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FORT MONMOUTH CHAPTER

ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION

LEVEL

PROCEEDINGS OF THE FIFTH ANNUAL SEMINAR

"THE ART OF COMMUNICATIONS INTERFACES"

c^3I ENVIRONMENT FOR THE 90s

21-22 OCTOBER 1980

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ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION

(6) PROCEEDINGS OF THE

ANNUAL SEMINAR (5th).

THE ART OF COMMUNICATIONS INTERFACES

C^3I ENVIRONMENT FOR THE 90s

21-22 OCTOBER 1980

P.O. BOX 825   (10) Bernard D. DeMarinis

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PROCEEDINGS INFORMATION

Requests for individual copies of the papers should be addressed to the authors. Extra copies of the proceedings may be obtained from the seminar chairman. Requests should include a check for $15.00 per copy, made payable to: "Fort Monmouth Chapter, AFCEA." Copies may also be obtained for a nominal fee from the National Technical Information Service (NTIS), Operations Division, Springfield, Virginia 22151.

Proceedings of the First, Second, Third, and Fourth Annual Seminars are available from the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. The First Seminar proceedings is numbered AD-A023907. The Second Seminar proceedings is numbered AD-A044407. The Third Seminar Proceedings is numbered AD-A061466. The number for the Fourth Seminar proceedings was unavailable at the time of this publication.

The First Seminar covered Fiber Optic Systems and Interfaces, the AN/TTC-39 TRI-TAC Switching Systems Interfaces, and Man-Machine Interfaces.

The Second Seminar discussed Strategic Systems Interfaces, emphasizing Access Area Switching Systems, Digital Tropo Modem Developments, and Tactical Data System Interfaces.

The Third Seminar addressed RSI in the C^3I arena, and the Fourth Seminar dealt with Technology Insertion in the C^3I Arena.

Bernard D. DeMarinis
Technical Editor

Project Engineer
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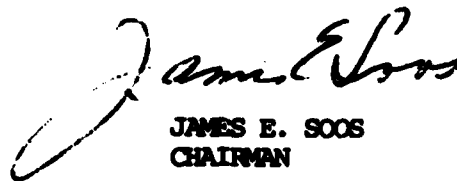
MESSAGE FROM THE GENERAL CHAIRMAN

The Fort Monmouth Chapter of the Armed Forces Communications Electronics Association presents a seminar highlighting battlefield environment that the Army will experience in the 1990's and command, control, communications and intelligence systems that are envisioned to cope with that environment.

The lethality of emerging weapons systems, both hostile and friendly, will create the need for commanders to have increasing amounts of information in ever shorter periods of time in order to execute timely and effective command decisions. Countering this information explosion are the need for ultra reliable and survivable networks composed of dispersed and highly mobile equipment configurations capable of withstanding intense enemy electronic warfare.

It is the purpose of this seminar to present "The C^3 I Environment of the 90's", and discuss the activities of the user and development communities in the Army, and of industry as they collectively respond to these new challenges.

We of AFCEA are grateful for the time and effort expended by the many committee members, speakers, and session chairmen, who were active in planning and promulgating this seminar. We also express our appreciation for their support and guidance to Lt General Richardson, Dr. Lasser, Major Generals Babers and Paige, and Messrs Diedrichsen and Schell.

In particular, we appreciate the cooperation of all the attendees of this seminar. Your dialogue, discussions and comments are most valuable in improving the seminar as a forum, and suggestions for future topics will be most welcome.

JAMES E. SOOS
CHAIRMAN

GENERAL CHAIRMAN

DR. JAMES E. SOOS

Dr. James E. Soos is the Director of the Communications Systems Center, CORADCOM. He received a BSEE from Iowa State University, an MSEE from Rutgers University, a PhD from Polytechnic Institute of Brooklyn, and an MS (Sloan Fellow) from Massachusetts Institute of Technology.

Prior to assuming his present position in October of 1979, Dr. Soos served as the U.S. Telecommunications Expert to NATO at the U.S. Mission NATO in Brussels, Belgium, from 1976 to 1979. Dr. Soos joined the Army Signal R&D Laboratories in 1958 and served in various positions as an electronics engineer for the Army until 1972 when he became Chief of the Plans Division of the TRI-TAC Office. In 1959, Dr. Soos served a six-month tour of duty as a Second Lieutenant, USAR, with the Corps of Engineers at Ft. Belvoir, Virginia.

Dr. Soos is additionally chairing Session III of this seminar.

TECHNICAL CHAIRMAN
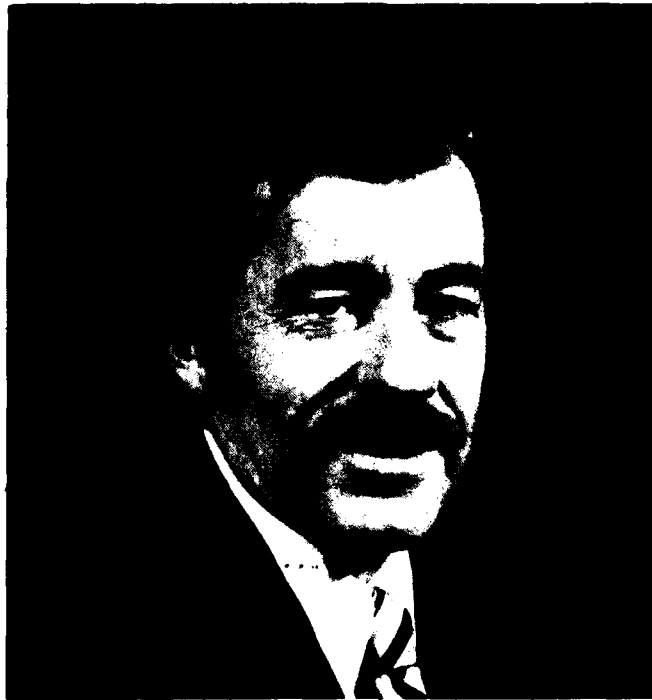
DR. THEODORE J. KLEIN

Dr. Theodore J. Klein has been associated with communications research and development at Fort Monmouth since 1958, and presently heads the Signal Processing Division of CENCOMS. His current work includes basic and applied research and development related to information distribution systems, record communications, optical character recognition, electromagnetic propagation, and digital multiplexing projects.

Dr. Klein holds a bachelor's and a master's degree in electrical engineering from Iowa State University and Rutgers University, respectively, and a doctorate in system engineering from the Polytechnic Institute of Brooklyn.

PRESIDENT, FORT MONMOUTH CHAPTER OF AFCEA
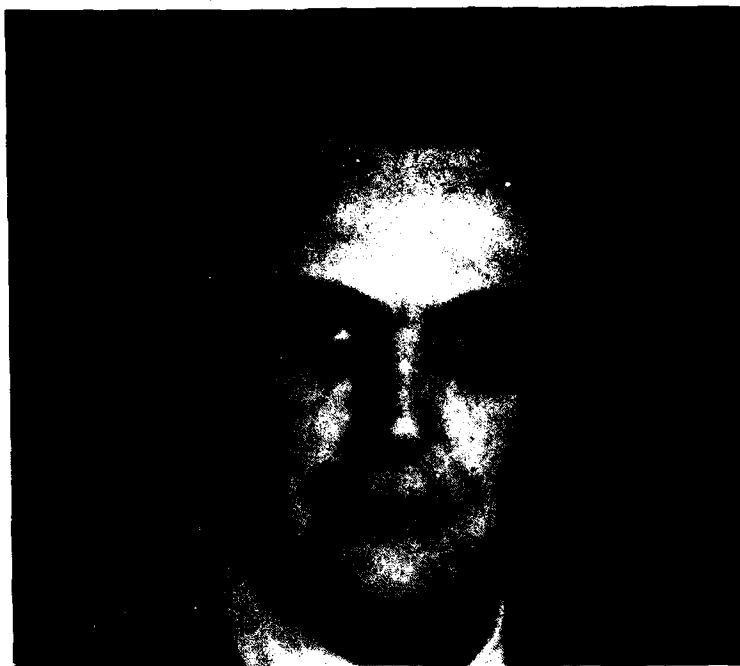
DR. ROBERT E. FRESE

Dr. Frese received a Bachelor's degree in Mathematics and a Bachelor's, Master's, and Doctoral degree in Electrical Engineering from the University of Michigan. He began his professional career as a researcher and consultant in the field of air defense system countermeasures and became an instructor and assistant professor of electrical engineering at the University of Michigan.

In 1959, he was appointed to a supergrade position at the U.S. Army Electronic Proving Ground and was later promoted in 1962 to Chief Scientist at Fort Huachuca. During this time, he served for four years as a member of the Board of Directors of Consumers Union of the U.S., Inc., the publisher of "Consumer Reports."

From 1963 to 1969, he was an executive in the Federal Systems Division of the IBM Corporation, responsible for application of data processing and lasers to tactical problems. In 1969, he became the Director of the Joint Engineering Agency for the international MALLARD Project, a joint tactical communications program by the U.S., U.K., Canada, and Australia.

In 1971, He assumed his current position as Deputy Director for Engineering of the OSD's Joint Tactical Communications (TRI-TAC) Office. He has also been Co-Chairman of the Committee on the Interoperability of Defense Telecommunications since its inception in 1973.

WELCOMING REMARKS
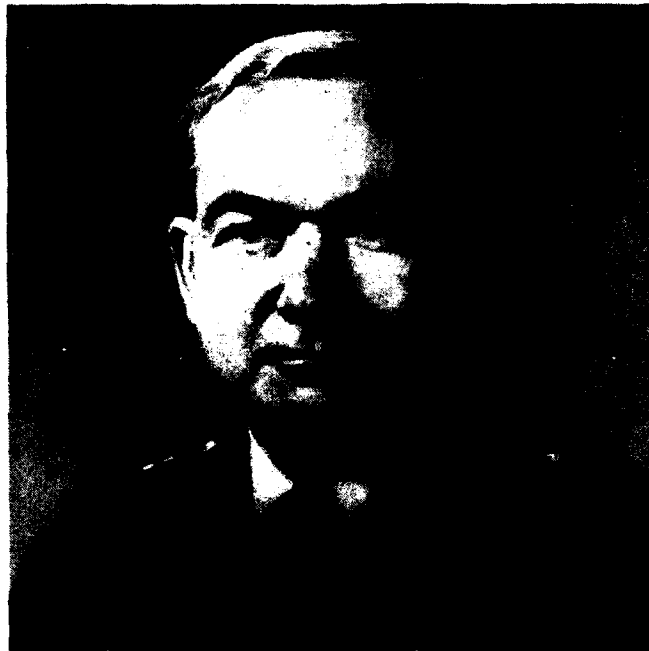
MAJOR GENERAL DONALD M. BABERS

Major General Donald M. Babers graduated from Oklahoma A&M College and was commissioned as a second lieutenant in the Ordnance Corps in 1954. He received his master's degree in business administration from Syracuse University.

Several key assignments in his twenty-five year military career included service as Commanding Officer of the Project Manager M561/XM705 Truck Vehicle Programs and Director for Procurement and Production, duty as Deputy for Logistics Support at the Tank-Automative Command, and an appointment as Commander of the 46th General Support Group, 18th Airborne Corps at Fort Bragg. He was promoted to Brigadier General in July of 1975 and was assigned to the U.S. Army Tank-Automotive Command in Warren, Michigan as the Director of Procurement and Production. In 1976, he was assigned as Deputy Commanding General of the same command. He served in this position until July of 1977 when he was appointed Project Manager, XMI Tank System. In 1978, he was promoted to Major General and this past June, Major General Babers became Commanding General of the U.S. Army Communications and Electronics Materiel Readiness Command at Fort Monmouth.

THEME SETTING REMARKS

MAJOR GENERAL EMMETT PAIGE, JR.

Major General Emmett Paige, Jr. received a BA degree in Business Admin-
istration from the University of Maryland and a Master of Public Admin-
istration degree from Pennsylvania State University. He attended the
Signal School, Basic and Advanced Courses, U.S. Army Command and General
Staff College, and the Army War College. His assignments have included
project officer in the UNICOM Systems Office, 1966, Deputy Project Manager
for IWCS, 1968, Chief of Voice Network Global Management Branch, Opera-
tions Directorate DCA, 1973, Deputy Chief of Staff, Army Communications
Command, Fort Huachuca, 1974, Commander of the 11th Signal Group, U.S.
Army Communications Command, 1975, and Commanding General of the U.S.
Army Communications Systems Agency/and Project Manager DCS Army Commu-
nications Systems/Commander, U.S. Army C-E Engineering Installation Agency
in 1976. He is currently Commander of the U.S. Army Communications Research
and Development Command.

Major General Paige has been awarded the Joint Service Commendation Medal,
the Bronze Star, the Meritorious Service Medal, the Army Commendation Medal,
and the Legion of Merit with two Oak Leaf Clusters.

BANQUET GUEST SPEAKER

LIEUTENANT GENERAL WILLIAM R. RICHARDSON

Lieutenant General Richardson graduated from the U.S. Military Academy at West Point in 1951. In 1968, he received his Master of Science degree in Business Administration from George Washington University.

After over twenty years of distinguished service in the military, General Richardson was appointed Commander of the 193rd Infantry Division in 1974. In July of 1977, he assumed duties as the Director of Requirements in the Office of the Deputy Chief of Staff for Operations and Plans, Headquarters, Department of the Army, in Washington, D.C.

General Richardson was appointed to his present position in the fall of 1979, when he was assigned duty as the Deputy Commanding General, U.S. Army Training and Doctrine Command, with duty station at Fort Leavenworth, Kansas. Concurrently, he became the Commander, U.S. Army Combined Arms Center and Fort Leavenworth, Commander, U.S. Army Combined Arms Combat Development Activity, Commandant of the U.S. Army Command and General Staff College, and Commander, Combined Arms Training Developments Activity, Fort Leavenworth, Kansas.

LUNCHEON GUEST SPEAKER
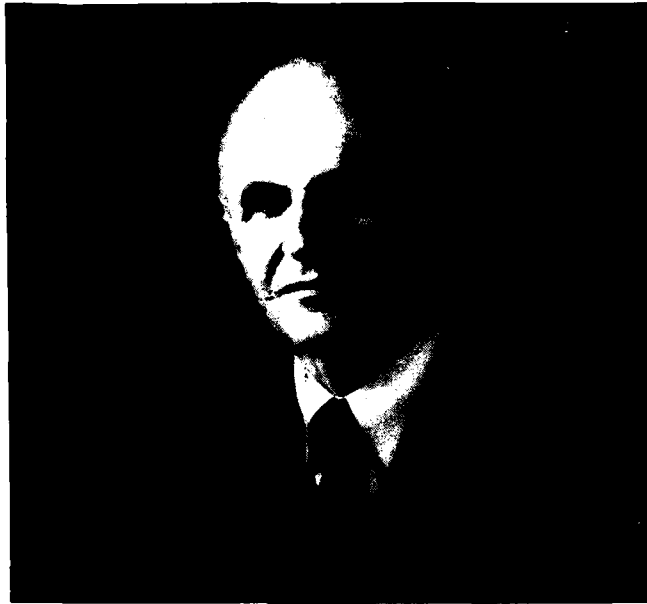
DR. MARVIN E. LASSER

Dr. Lasser received his BA degree in physics from Brooklyn College in 1949, and his MS and PhD degrees from Syracuse University in 1951 and 1954, respectively. After he received his doctorate, he joined the research division of Philco Corporation as a project scientist in 1954. In 1956, Dr. Lasser was promoted to Research Section Manager in charge of a group studying energy conversion phenomena and was subsequently appointed Manager of Applied Research. In 1964, Dr. Lasser was appointed Director of the Applied Research Laboratory, the central laboratory for the corporation.

In June of 1966, Dr. Lasser was named Chief Scientist, Department of the Army, and in July of 1970, he became Executive Director of the Army Scientific Advisory Panel. He was appointed to his present position as Director of Army Research on May 20, 1974. Dr. Lasser is currently responsible for ensuring that the Army's technology base program is responsive to the specific needs of the Army.

CHAIRMAN --- SESSION I

MR. LOREN DIEDRICHSEN

Mr. Diedrichsen serves as the Director of the U.S. Army CORADCOM Center for System Engineering and Integration (CENSEI). Prior to assuming that position in December of 1979, he served for seven years as the Chief of the TRI-TAC Office Systems Division.

In his present position, he is responsible for the system engineering, integration, and interoperability of all Command, Control, and Communications (C^3) Systems used by the tactical forces of the U.S. Army for the execution of research and development work in the area of systems technology.

Mr. Fremont received a BS in Electronic Engineering in 1958 from Iowa State University and an MS in Management Science (Operations Research) in 1967 from Stevens Institute of Technology.

He has received the Department of Army decoration for Exceptional Civilian Service and was twice awarded the Decoration for Meritorious Civilian Service. He is a member of the Board of Directors of the Fort Monmouth Chapter of AFCEA.

MR. JAMES E. SCHELL, II

Mr. Schell received his baccalaureate degree from Morehouse College, Atlanta, Georgia, in Mathematics, Physics, and French. Mr. Schell was a charter member of the Project Manager's Office, Command Control Information Systems, 1970 (CCIS-70), where he held the position as Project Manager Staff Officer at Fort Monmouth, New Jersey. He subsequently left Government service to enter private industry to direct computer software development and support activities with Metasystems, Inc. He later joined Litton Industries, attaining the position as Director of the AN/TTC-39 and TACFIRE/TOS Programs.

In November of 1979, Mr. Schell accepted an appointment as a member of the Federal Senior Executive Service (SES). He has assumed the position as Director of the Center for Tactical Computer Systems (CENTACS), U.S. Army Communications Research and Development Command (CORADCOM).

SEMINAR COMMITTEE

LT. COLONEL BILLIE N. THOMAS
REGISTRAR - INDUSTRY

Billie N. Thomas was born in Mason, Texas. He received a Bachelor's degree
from the United States Military Academy at West Point in the class of 1962.
He earned an MSEE in 1969 from the University of Arizona and an MBA from Long
Island University in 1969 and 1974, respectively.

Colonel Thomas was Director of Support Operations, U.S. Army Communications
Research and Development Command, Fort Monmouth. His duty assignments included
Commander, DaNang Signal Battalion, Operations Officer of the 37th Signal Bat-
talion, Staff and Faculty at the United States Military Academy, Executive
Officer, PM ARTADS, Commander, 5th Signal Battalion, Fort Polk, Louisiana, and
Communications Team Chief, ODCSRDA, DA.

His military decorations include the Bronze Star, three awards; the ARCOM,
three awards; and other service ribbons.

He was Secretary of the Fort Monmouth Chapter, Armed Forces Communications
and Electronics Association, and is Registrar for the Fifth Annual Seminar.
He retired from active service and is a systems analyst with Teledyne Brown
Engineering Company.

MR. JOSEPH DOUGHERTY
REGISTRAR - GOVERNMENT

MR. BERNARD D. DEMARINIS
TECHNICAL EDITOR

Mr. DeMarinis is a Project Engineer at Booz, Allen & Hamilton Inc. He has
more than twelve years of experience in fiber optics, satellite communica-
tions systems, digital tropospheric systems, and ECM systems. He has been
extensively involved with military inventory radio equipment assemblages and
their tactical and strategic communications interfaces.

Mr. DeMarinis received his BEE from the City College of New York and his MSEE
degree from the Polytechnic Institute of Brooklyn. He is presently Second
Vice President for the Fort Monmouth Chapter of AFCEA and was Technical Chair-
man of the Second Annual AFCEA Art of Communications Interfaces Seminar.
Mr. DeMarinis has been an officer of the Microwave Theory and Techniques, An-
tennas and Propagation, and Circuit and Systems Groups of the IEEE, and was
General Chairman of the 1976 International Microwave Symposium. He was also
Technical Chairman and General Chairman, respectively, of the 1977 and 1978
AFCEA Art of Communications Interfaces Seminars. Additionally, he served
as Technical Editor for the 1979 AFCEA Proceedings. He was Chairman of the
Princeton Section IEEE and is a member of AFCEA, the Association of Old Crows,
ADPA, AUSA, Tau Beta Pi, and Eta Kappa Nu. Mr. DeMarinis was chosen as AFCEAN
of the Month February 1980.

SEMINAR COMMITTEE

MRS. BARBARA ANN FISCHER
COORDINATOR

Mrs. Fischer has been associated for eighteen years with the Regional Marketing Office of GTE Products Corporation, Communications System Division, in Tinton Falls, New Jersey.

She received an AA degree from the Institute of Human Affairs, Brookdale College, Lincroft, New Jersey, and has continued her studies at Monmouth College, West Long Branch, New Jersey.

Currently, she is Vice President for Membership and Editor of the Chapter Newsletter of the Fort Monmouth Chapter, Armed Forces Communications and Electronics Association.

She has been an active participant in the chapter's past seminars, and this year, she serves as Coordinator for the planning and administration of the Fifth Annual Seminar.

Mrs. Fischer was chosen as AFCEAN of the Month in April of 1979 by National Headquarters and was the recipient of the Meritorious Service Award in June of 1979 at the National Convention in Washington, D.C. She was awarded the Fort Monmouth Chapter's 1979 "Dr. Harold A. Zahl Memorial Award." She was also chosen by the AFCEA Chairman of the Board to receive one of the three Distinguished Service Awards presented at the AFCEA Annual Convention in June 1980.

MR. V. MICHAEL CAPUTO
LUNCHEON CHAIRMAN

Mr. Caputo is Director, Army C^3 for The BDM Corporation, and the manager of BDM's Shrewsbury office. He has over 18 years of management experience in systems engineering, management engineering, R&D, and acquisition management, including ten years of direct involvement in Army and joint Service tactical and strategic C^3I programs.

Mr. Caputo earned a B.S. degree from the U.S. Military Academy in 1962, and an M.S. degree in Engineering Management from C. W. Post College (Long Island University) in 1969. Following his graduation from West Point, he served in the U.S. Air Force in Air Force and joint Service intelligence assignments, and as a base civil engineer, and an Air Force Academy Liaison Officer. His civilian background includes program management experience in the Safeguard and EA-6B programs. During the past six years, he has been providing professional services support to Army and joint Service tactical C^3 programs.

He is a member of AFCEA, AUSA, Industrial Representatives Association, and the Signal Corps Association. He is an advisor to the Institute of applied Humanities at Brookdale Community College, and an Adjunct Professor of Business at Ocean County College.

SEMINAR COMMITTEE

MR. WARREN WOLFF
EXHIBITS CHAIRMAN

Mr. Wolff is Manager of Program Development for Analytics SENCOM Group in Tinton Falls, New Jersey.

He has more than eighteen years of experience in systems engineering and acquisition management for defense and civil systems. He has been extensively involved in programs for command, control, and communications systems for all services, military and civil air traffic control systems, weapons and public safety communications systems.

He received a BEE from City College of New York and an MS in Engineering Management from Northeastern University. He has taken doctoral studies in Operations Research at New York Polytechnic Institute.

Mr. Wolff is a member of the IEEE, Human Factors Society, the Society for Information Display, the Air Traffic Control Association, Tau Beta Pi, and Eta Kappa Nu.

Mr. Wolff is presently Treasurer of the Fort Monmouth Chapter of the Armed Forces Communications and Electronics Association, and is an active member of the Fort Monmouth Chapters of the Association of the United States Army, Association of Old Crows, and the Industrial Representatives Association.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

SESSION III   Page

Chairman -- Dr. James Soos
Director, CENCOMS CORADCOM

AN APPROACH TO A C^3I SYSTEM

FOR THE 1990'S

by

Dr. Theodore J. Klein

Center for Communication Systems
U.S. Army Communications Research
and Development Command

and

Frank E. Owens

MITRE Corporation, C^3 Division

1

1.0 INTRODUCTION

Command Control Communications and Intelligence (C^3I) Systems exist to facilitate the accomplishment of the U.S. Army Tactical Combat mission.

The effectiveness of a military force depends upon its ability to move, shoot and communicate. Mobility, firepower and the ability to control the application of combat resources through C^3I Systems give the commander the means to wage war on the modern battlefield. The Army Command and Control Master Plan (1) and the Division 86 study (2) strongly support the conclusion that the predominately manual C^3I Systems currently in use will not provide the tactical commander with sufficient, accurate and timely information about the enemy situation and friendly forces which would enable him to make the necessary decisions for the successful accomplishment of his mission. This is particularly true when he is opposed by a modern, highly mobile, well equipped enemy like the Warsaw Pact forces. There is, therefore, an urgent need for an integrated C^3I System employing current state-of-the-art advances in automation and electronic communications so as to assure that timely and accurate information flow will be made available to our tactical commanders, and from them to the troops who carry out their orders.

1.1 C^3I System Support for Major Tactical Functional Areas

Tactical Combat Operations are centered around five discrete functional areas of responsibility each having readily identified Operational Control Centers.

- Manuever Control
- Fire Support
- Air Defense
- Intelligence & EW
- Combat Service Support

Each of the above operational facilities is dependent upon information flow within its area of responsibility and upon the exchange of portions of this information with the other operational facilities concerned with tactical combat actions. Information flow in turn is dependent upon the communications means available to transport it. The key to effective communications performance has always been the time required to move information from its origin or source to all those entities which may be impacted by the information. Thus, time is a key factor on the battlefield; time to move friendly forces and materiel, and time to sense the state of the enemy forces so that targets can be identified and action taken to destroy, neutralize or otherwise impact the targets. The time required to distribute and deliver the information which provides the basis for a decision to maneuver forces or to shoot at a target is the most critical factor of all, and in many cases is the determinant

of either success or failure. The pace of technological advancement appears to be rapidly shrinking this time scale.

Experience on the modern battlefield (ARAB-ISRAELI WAR 1973), during field exercises, and in war games and simulations has clearly indicated that the use of Korean War vintage communications means to move information coupled with manual methods of correlating, filtering and assessing information does not provide sufficient time for tactical commanders and staff officers to sense the enemy and the friendly situation and thereby make reasonable and effective decisions with respect to mission accomplishment. Given this kind of situation uncertainty increases. The term "the fog of war" describes a situation where visibility is clearly lacking and decisions are made based on flimsy assertions instead of on hard facts. This kind of decision-making often leads to drastic actions like: surrender of superior forces to inferior ones, (Singapore 1942), sending reserves to the wrong place at the wrong time, (France 1940), - in short, chaos.

New roles and missions projected for tactical army forces like the Rapid Deployment Force (RDF)mission (Figure 1.0), fighting the 2nd echelon battle in Central Europe, Helicopter Antitank Operational doctrine and Shoot and Scoot Artillery doctrine (Figure 2.0), place even more stringent time constraints on the C^3I System. The communications connectivity and electronic processing support necessary to meet such time constraints are just not possible with today's equipment and procedures, even though technology exists which could be applied to this task.

We all know that by electronic means we can move information between two points at the speed of light-we also know that with a digital computer we can accomplish thousands of operations in a second-but for effective and timely communications we need connectivity, not just between two points, but among all the elements in a Division or Corps (more than a thousand) which generate information, and correlate, assess or otherwise act on information. Effective and timely communications implies that connectivity be provided between users whenever information flow is required even though the users may be spread over a wide geographic area and several dissimilar communication networks or media may be required to provide such connectivity.

However, to provide the connectivity between all the elements engaged in tactical operations so that information can be moved in near time, is only half the solution-the information when it arrives must be correlated with other information, filtered, aggregated, singled out, or otherwise processed so that it can be easily acted upon based on its information content. Manual processing of this information simple takes too much time to provide a basis for tactical actions on the modern battlefield.
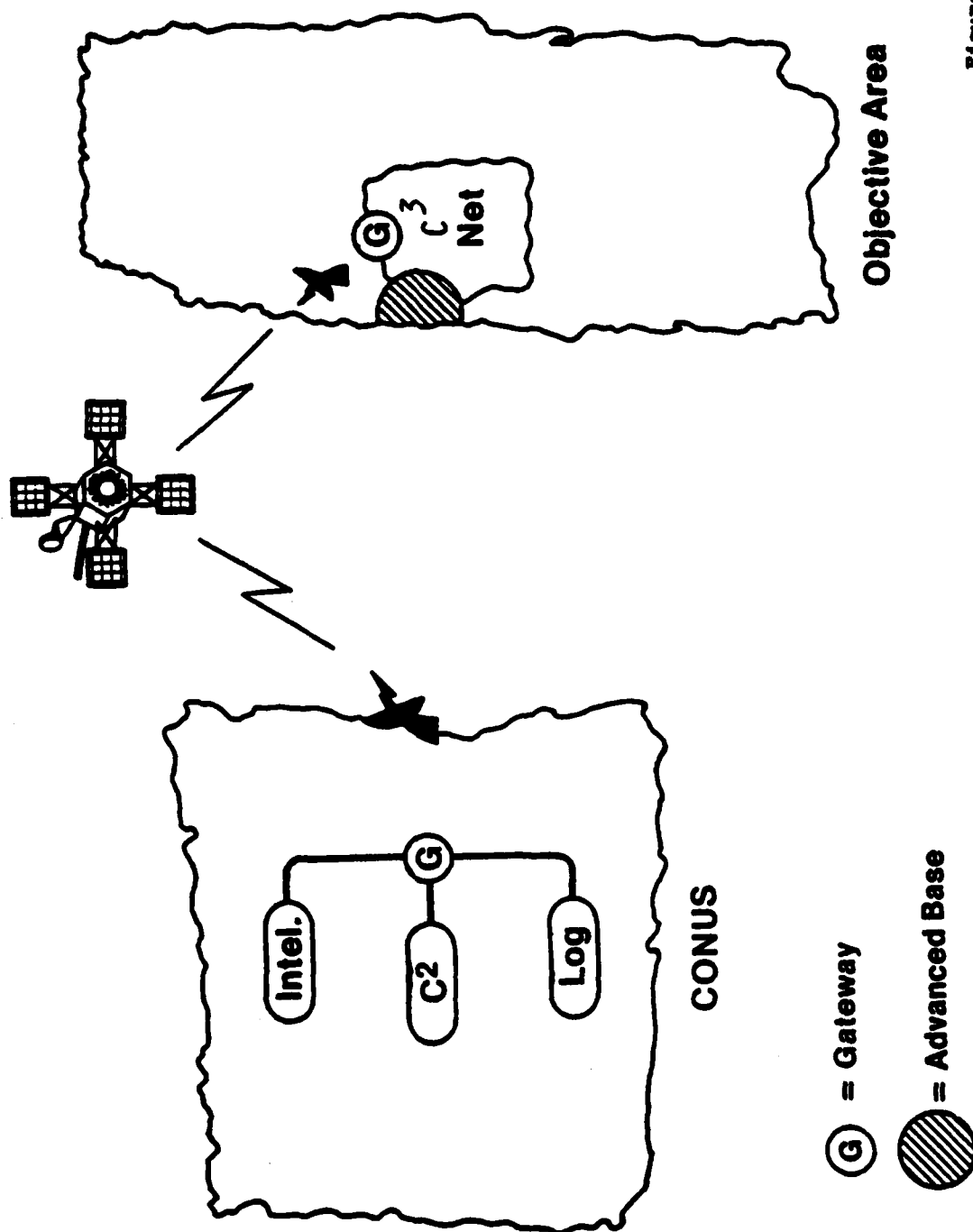
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RDF Scenario

Objective Area

G C³ Net

CONUS

Intel.   C²   Log   G

Ⓖ = Gateway

⬤ = Advanced Base
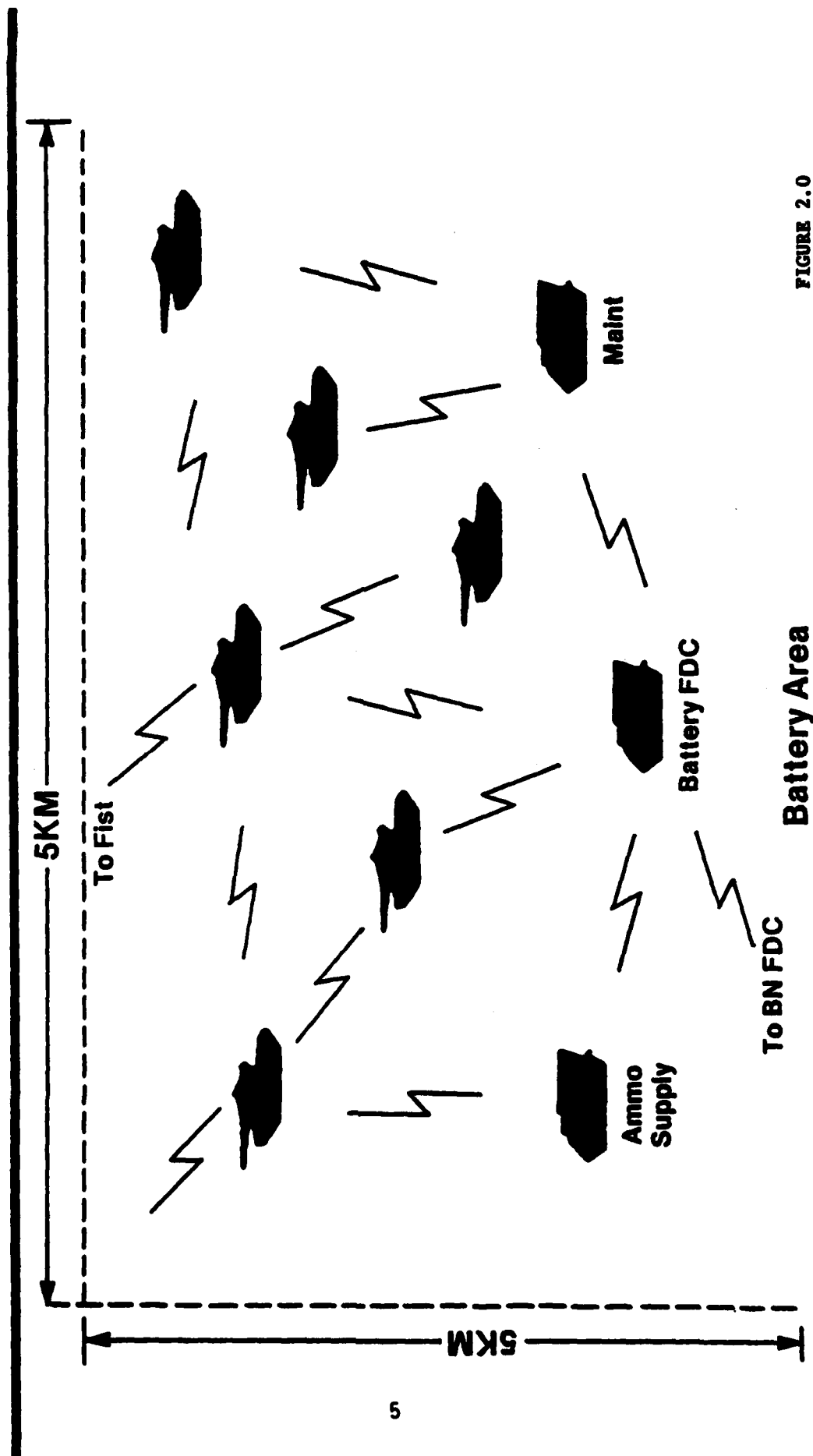
Figure 1.0

4

Scoot and Shoot Scenario

FIGURE 2.0

5

Electronic processing capability is required and these proces-
sors must be campatible with the electronic communications means if
time to move and process information is to be minimized. Thus the
battlefield information distribution system needed is one that
comprises electronic communications means which are compatible with
the electronic processors that make up the subordinate functional
control systems.

System design must take in the human factors aspects as well
since unless a human can easily assimilate the information made
available to him a correct and timely decision still may not be made
even though the information conveys an accurate representation of the
tactical situation in near real time.

2.0 A BASIC ARCHITECTURE

Figure 3.0 depicts in gross terms a basic C^3I architecture.
The kernel of the architecture is the electronic communications means
which must be secure, survivable, flexible, responsive, have anti-
jamming protection and possess all those other desired attributes
necessary to distribute information in an error free mode in near
real time around the battlefield.

The communication means initially must be an internetwork
architecture composed of tactical multichannel and single channel
radio systems, switched systems, satellite nets, and High Frequency
radios. Developmental radio-based information distribution systems
such as the PLRS/JTIDS Hybrid and Packet Radio must be integrated
into the system as well.

The system must serve a variety of tactical users which range
from individuals who interface the network with a terminal of one
kind or another (usually an intelligent terminal), to the functional
operational control systems, mentioned earlier, comprised of one or
more processors and a variety of input/output devices. The informa-
tion distribution system must support information flow from an
individual terminal to other terminals, from terminals to processors,
from processor to processor, and from processor to terminal. A
terminal device is defined as an entity which originates and/or
receives information to or from another entity in the network. Some
terminals may in fact be sensors of one kind or another which generate
information automatically when stimulated.

In order to build a base of technology from which a battlefield
C^3I information distribution system can be evolved, each layer of the
network shown in Figure 3.0 must be investigated.

Surrounding the communications kernel is a layer titled
security. Near real time information flow would be counterproductive
if it could be easily accessed by the enemy. Network security issues
are necessarily a high priority R&D effort.

6

TACTICAL FUNCTIONAL SYSTEM INTERFACE

NETWORK MANAGEMENT AND CONTROL

SECURITY

COMMUNICATIONS MEANS

USER INTERFACE
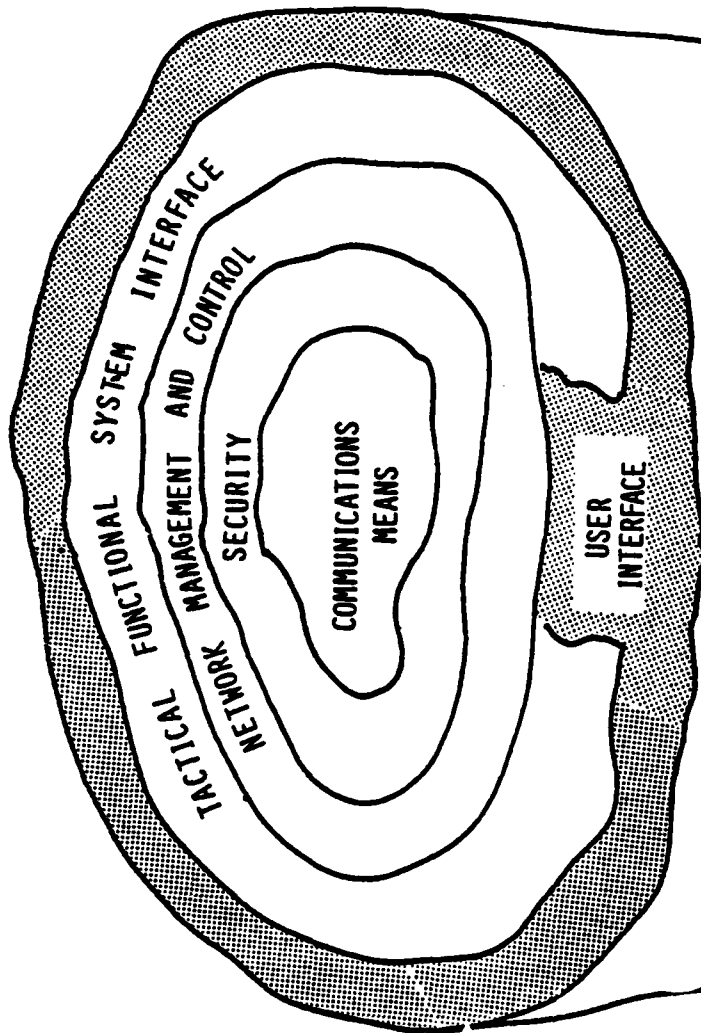
BATTLEFIELD INFORMATION
DISTRIBUTION NETWORK
LAYERS

FIGURE 3.0

7

Since a division is comprised of several hundred entities which require information flow, and a corps more than one thousand entities, the network which connects these entities must be quite extensive to be effective (i.e., have sufficient capacity, be survivable, flexible, reliable, etc.). A mechanism to manage and control the network in near real time must be developed-this requires, of course, a variety of hardware and software tools which must be developed and integrated. Of course, for increased survivability, this network control function should be distributed. The next layer in Figure 3.0 represents this mechanism.

The next layer concerns the functional control systems found on the battlefield which must have information distribution capability both within their own system and from their functional system to other functional systems and/or the executive system. This layer represents in essence one class of users which have their own processors but still require connectivity from the distribution network.

Finally, the last layer, entitled "user interface" addresses the individual entity which must have access to the network. The type of input/output device available to the user is a key factor with respect to ultimate utility of the information distribution network. The ease with which the user can insert information into the network and the ease with which he can retrieve, display and assimilate the information available from the network will determine the ultimate effectiveness of the network. Figure 4.0 provides another representation of a basic network configuration.

It can be seen that the communication means that must be examined include both current and developmental technology. Distributed control systems are needed which are compatible with both of these technologies. User level protocols and standards will be needed to facilitate the flow of information across dissimilar networks. Associated hardware and software interfaces will also be required.

It is unrealistic to expect that the current systems, manual or otherwise, will be replaced in one giant cutover to a new all digital system. Rather there must be a gradual transition phase wherein we must get the maximum mileage out of our current technology, while exploiting new technology to enhance the overall C^3I System capability.

The ultimate objective of a C^3I System for the 1990's would be to provide a capability that totally integrates processing power and communications power into a cohesive distributed data network which could survive in a tactical environment.

The network would provide for storage and processing of essential C^2 information in multiple locations, assured availability of software programs for any of the functional responsibilities associated with tactical operations, and communications means that would provide access to any or all of the functional processors on a selective basis.
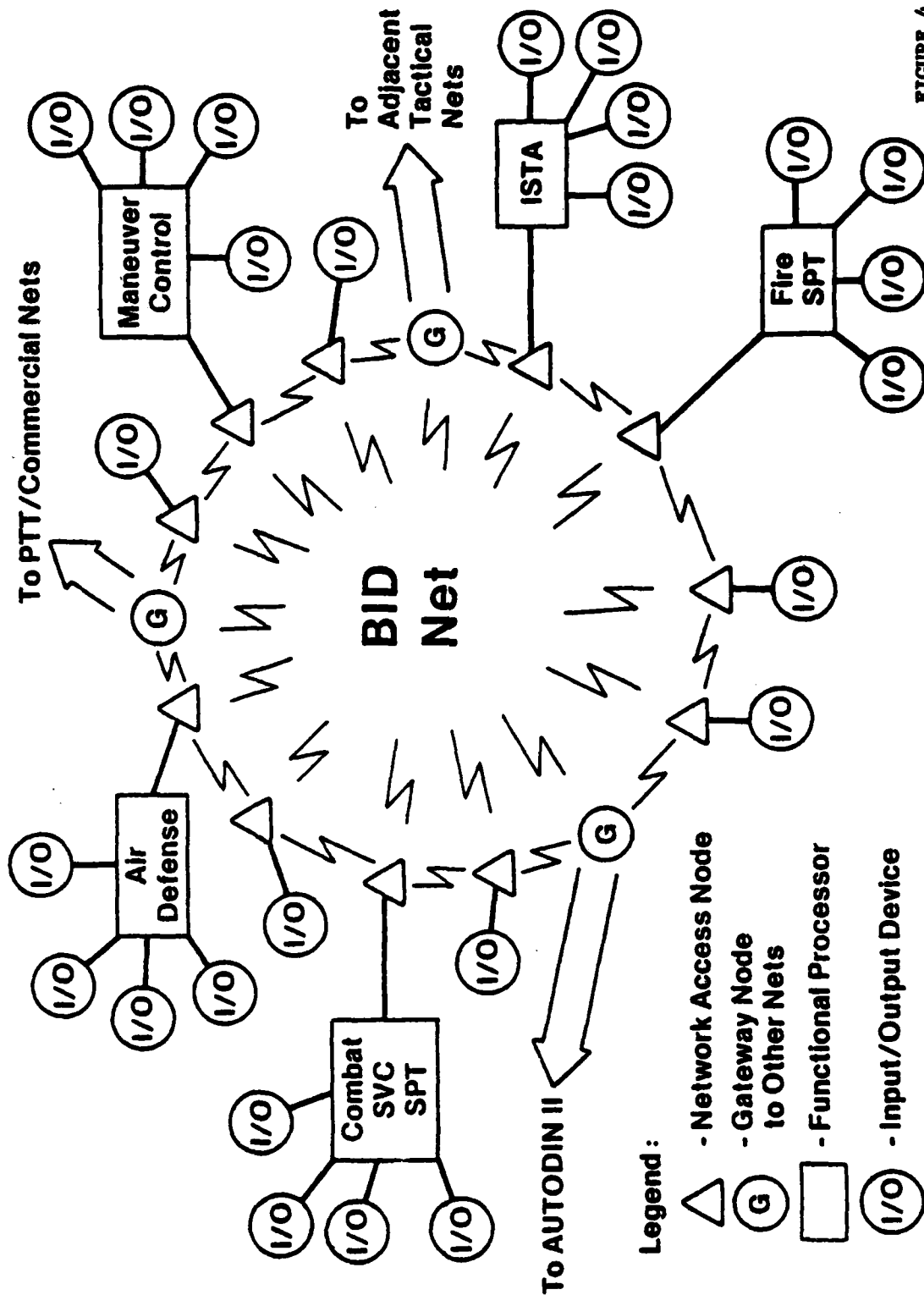
8

Battlefield Information Distribution

FIGURE 4.0

9

In short the network would provide near real time information flow between network users and access to sufficient processing power for any user whose tactical functions might require processor assistance. To be effective in a tactical environment the network must be secure, support mobile operation, accomodate large numbers of users (hundreds) and provide voice and facsimile service as well as record data.

3.0 GETTING THERE

To achieve an effective C^3I System in the 90's there are several important areas of hardware and software research, and conceptual doctrine which must be thoroughly investigated and integrated in the next few years if the network is to be operational in the 1990's.

CORADCOM through its Program Managers is currently engaged in a wide range of developmental efforts which will provide many of the components for the future C^3I System (See Figure 5.0). The CORADCOM Research and Development Centers are engaged in a broad range of developmental efforts directed towards building a base of technology which will provide the basis for the architectual design of the C^3I System of the 1990's. CENCOMS is conducting basic research and exploratory, advanced and engineering development to support C^3I requirements; wideband spread spectrum radios, digital COMSEC, fiber optic technology, digital signal processing, electromagnetic propagation and compatibility, packet switching and communications network management and control represent some of its current projects.

CENTACS is engaged in the vital R&D effort associated with the military computer family (MCF) Concept, distributed Data Base Management software, the higher order military oriented programming language Ada, which will form the basis for natural military language application software; to name but a few of its efforts. These key hardware and software research efforts will help determine the ultimate C^3I System architecture for the 1990's.

CENSEI, the Center for Systems Engineering and Integration, is engaged in a variety of efforts aimed towards integrating the diverse subordinate systems that now exist and providing for ease of future integration by the development of standard data elements, message formats, and communications protocols that can easily be implemented when the MCF Concept and Ada become a reality. In addition the very critical system engineering analyses, for the transition from the voice dominated analog systems of today to the all digital systems of the 1990's is a high priority CENSEI effort.

However pertinent CORADCOM's R&D efforts may be towards attaining the C3I System for the 1990's we must remember that these efforts represent only a part of the task associated with Army Tactical System Development. Three major Army Commands are involved in tactical system developments. TRADOC is responsible for concept development,

CORADCOM R&D Efforts Related to Battlefield Information Distribution

PM, OPTADS (Operations Tactical Data Systems)

PM ADCC (Air Defense Command and Control Systems)

PM TACFIRE/FATDS (Tactical Fire Direction System/Field Artillery Tactical Data Systems)

PM PLRS/JTIDS (Position Location Reporting/Joint Tactical Information)

PM ATACS (Army Tactical Communications System)

PM MSCS (Multiservice Communications Systems)

PM SINCGARS (Single Channel Ground and Airborne Radio Subsystems)

PM TMDS (Test Measurement and Diagnostic Systems)

FIGURE 5.0

11

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FORSCOM for user requirements, and DARCOM for materiel development, test and evaluation.

The normal text book sequence of events associated with system development is often stated as follows:

Requirement Generation   (USER-FORSCOM)
Concept for use.   (COMBAT DEVELOPER-TRADOC)
Development of hardware and software ⎫
Test and Evaluation   ⎬   DARCOM
Procurement   ⎭

This seems to be a quite logical and orderly management approach to developing systems for the battlefield. Why then does it take us so long to develop and field new systems?

Dr. William J. Perry, Under Secretary of Defense for Research and Engineering, recently pointed out that although the United States is five years ahead of Russia in technology it does us little good if our acquisition cycle is twelve years and theirs is only seven years in length. One reason for the long U.S. acquisition cycle has been the inability to integrate or apply the technologic base against user operational requirements. All too often in the past, technology has proceeded through advanced development and engineering development on the basis of hazy, ill defined operational requirements. Hardware and software items are provided to the users for the first time during DT/OT. User dissatisfaction becomes known only after DT/OT is completed. This often requires extensive modifications and sometimes a return to the advanced development phase for a system. We can no longer afford to wait for DT/OT to get new technology into the hands of the user.

Still another factor is the integration of the doctrine developer. If doctrine and materiel are developed out of synchronization with each other the acquisition cycle is often lengthened-since one or the other must wait for the laggard to catch up.

The Army is attempting to correct this difficulty by the recent TRADOC institution of the TSM-TRADOC Systems Manager or Concept Developer to work with the DARCOM Materiel Developer (Project Manager) for major systems.

Another step which can be taken to shorten the acquisition cycle is to bring the technology base and the user together to promote user generation of new requirements from a position of understanding new technology, and how it might, or should, impact on concepts and doctrine. Such a step is being taken, and is exemplified by the Army Data Distribution Systems (ADDS) experiments being conducted at Fort Bragg, N.C. under the provision of an MOU between DARPA, DARCOM, TRADOC, and XVIII Airborne Corps.

In this series of experiments State-of-the-Art hardware and software-not yet militarized-is provided by DARPA and CORADCOM to operational units for day to day use in developing concepts for use of hardware and software of a similar type in tactical operations. What should evolve is doctrine for use of this State-of-the-Art technology together with performance information on which a militarized version of the technology may be specified for the materiel developer. Successful integration of this type would insure that many of the problems currently experienced in DT/OT would be eliminated. In effect the ADDS experiment serves as a bridge between the concept developers/user community and the materiel developer community.

Further, only those systems for which a firm operational concept and materiel specifications were determined in experimentation, would proceed beyond the exploratory development stage.

4.0   THE EXPERIMENTAL C^3I NETWORK TESTBED AT FORT BRAGG, N.C.

To understand how an activity like the ADDS experiment at Fort Bragg, N.C. can function as a means of integrating the efforts of the materiel developers at CORADCOM, the concept developers at TRADOC and the tactical Corps users towards a common goal-it would be useful at this point to describe the experiment in greater detail.

The experiment is directed towards building a base of technology which can be used to improve the flow of information on the battle-field in the 1990's. A notional tactical corps data distribution net-work has been established using developmental hardware and software and some off-the-shelf commerical hardware to provide a vehicle for experimentation. This experimental network is being used to investi-gate and shed light on the process called "battlefield information distribution."

Each of the three participating Army Commands and DARPA have provided resources for the Fort Bragg experiment. The Executive Committee of the experiment is comprised of General Officer level representatives of TRADOC, DARCOM, FORSCOM, and DARPA and provides the broad policy guidance for experimental activity.

The experimental testbed provides a tactical "real world" forum which allows for iterative interactions of the previously mentioned elements prior to formal system design, specification and deployment-doctrine formulation. The basic inputs to the experiment as shown in Figure 6.0 will be (1) developmental material (new techno-logy), (2) concepts and (3) user requirements, provided by DARCOM/ DARPA, TRADOC and XVIII Airborne Corps (FORSCOM), respectively. The output of the experiment will primarily be information/data feedback as part of an ongoing cooperative process between the major players with the express intent of evolving a generic distributed data system that will possess those attributes necessary to meet the objectives of the Army C^2 Master Plan. The results of the various experiments
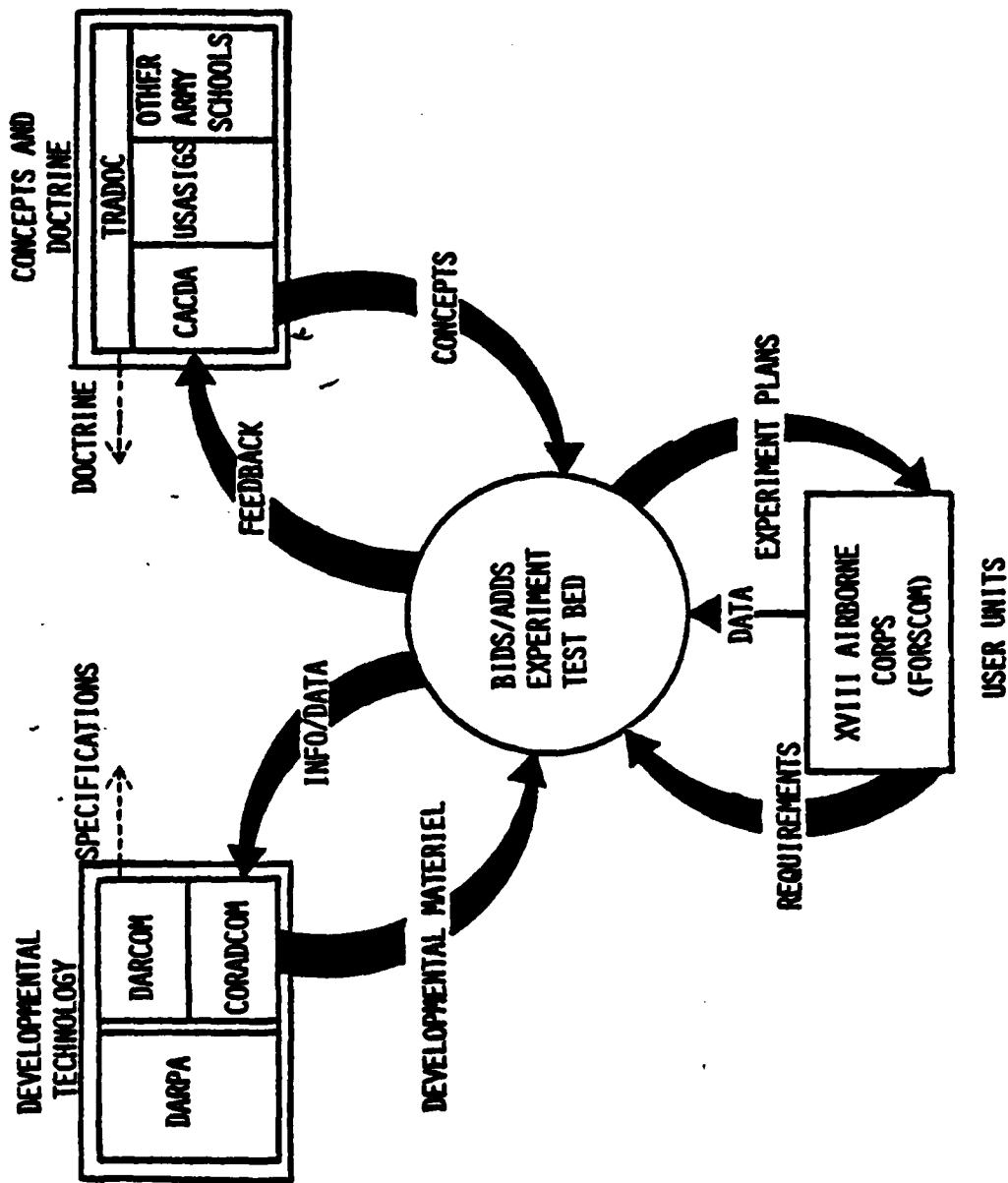
13

FIGURE 6.0

BATTLEFIELD INFORMATION DISTRIBUTION/ADDS EXPERIMENT CONCEPT

are expected to provide a foundation of knowledge from which the
users and Concepts/Doctrine Developers (TRADOC/CACDA/USASIGS) can
formulate more definitive requirements. These will in turn allow
the material developers to prepare more definitive specifications.

4.1 Accomplishments to Date

The experimental network currently in being at Fort Bragg con-
sists of more than 50 terminals (Input/Output devices) distributed
to key tactical elements at Fort Bragg and two terminals located at
the 101st Airborne Division, Fort Campbell, Ky. (Figure 7.0, 8.0).
These terminals have access to the experimental net participants and
to the ARPANET by means of hardwire connection to the Terminal
Interface Processor (TIP) at Fort Bragg or by means of Packet Radio which
is in turn connected via a gateway to the ARPANET. Figure 9.0 and
10.0 depict the experimental network topology. Processing power is
provided by a large scale computer (DEC-20) located in Los Angeles,
California.

More than 500 military personnel have been trained to date in
the use of the terminals to access network resources.

The network resources are being used for a variety of applications
by the various Corps units day to day in garrison right now-these
range from simple word processing applications like preparation of
recurring reports to on-line weather information. Keep in mind that
the availability of the Packet Radios allows users to take their
terminals to the field during exercises and maintain connectivity
which allows them to continue to perform their routine tasks as well
as exercise associated tasks while they are in the field. (Figure 11.0)

In reviewing progress to date, it is important to note that
significant inroads have been made into the Tactical Army's "credi-
bility gap" with respect to data processing and data communications.
The pool of trained individuals in operational units keeps growing
and the utility of the network at Fort Bragg is increasingly appreciated.
The single most significant shortcoming of the experiment perceived
thus far seems to be the experimental network's inability to handle
classified data. Intensive efforts to rectify this problem are
currently underway.

The successful establishment of the experiment in an operational
environment indicates that the stage has been set for important and
exciting advances in Army oriented distributed data systems incorpor-
ating high speed and high capacity data communications.

Proposed plans for experiment activity for FY81 through FY85 call for
investigation of 16 key areas (Figure 12.0) that cover tactical
concepts, user applications, and software/hardware technology that
must be examined if we are to field a C3I System in the 1990's which
has some hope of meeting the perceived requirements. It can be seen

PHASE 1 INSTALLATION
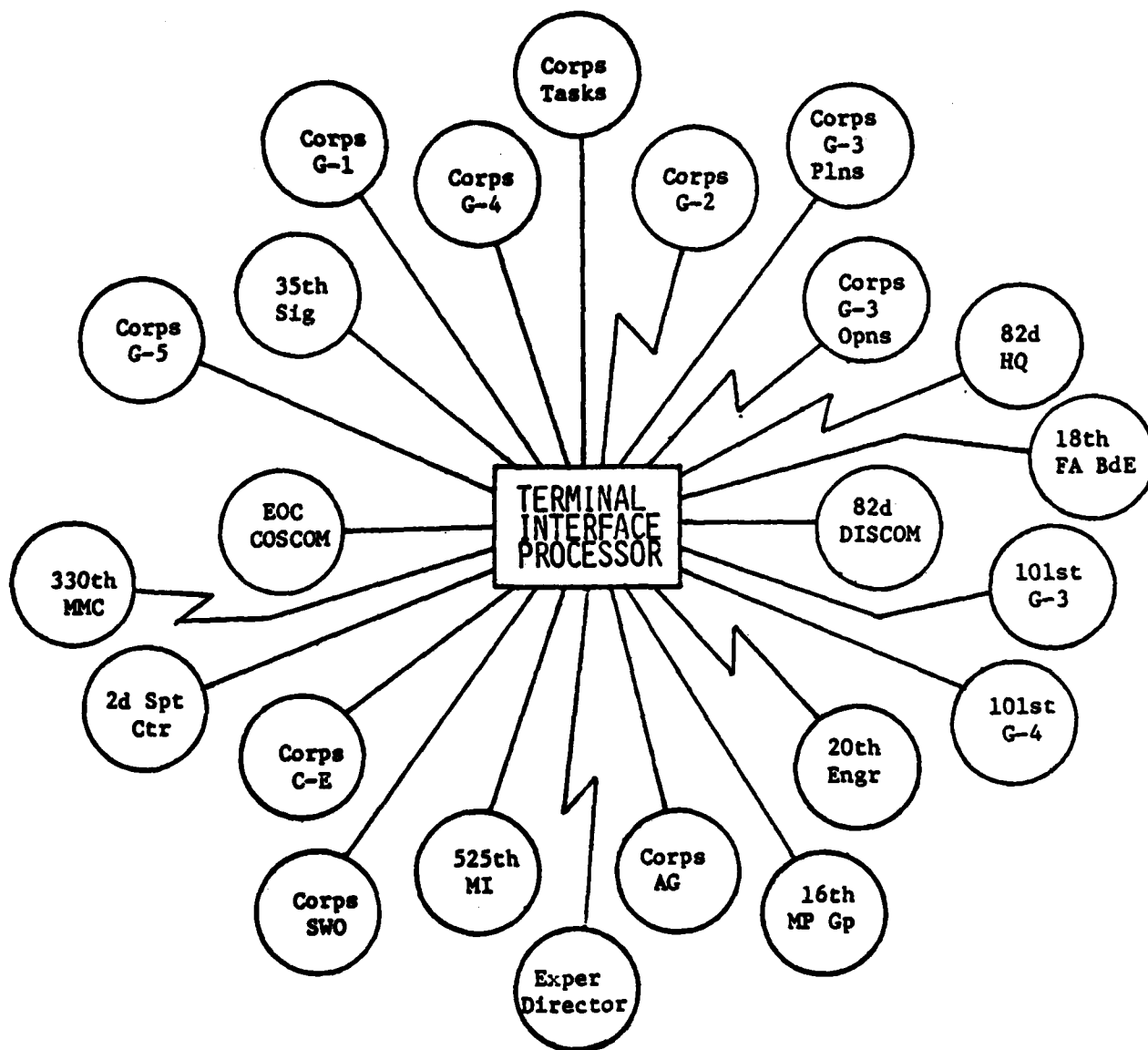
Lightning flashes denote terminals connected or to be connected to Packet Radios.

Figure 7.0
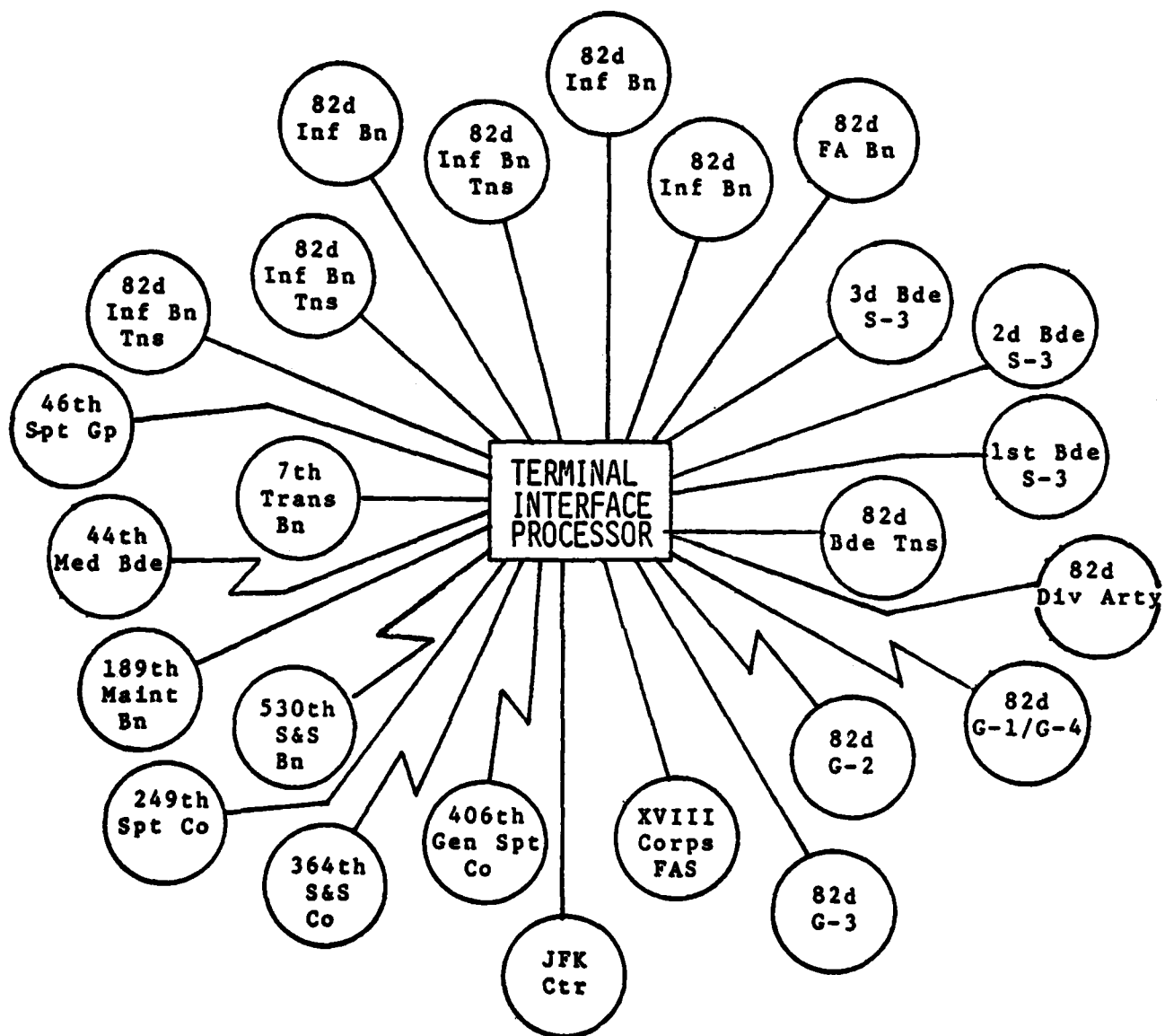
Lightning flashes denote terminals connected or to be connected to Packet Radios.

Figure 8.0

BID/ADDS Experiment Topology

ARPA Net

XVIII Airborne Corps BID/ADDS Net

TIP Ft. Bragg

TIP

101st Airborne Terminals

IMP

ISID Los Angeles, CA

DEC 20

Processor

FIGURE 9.0

18
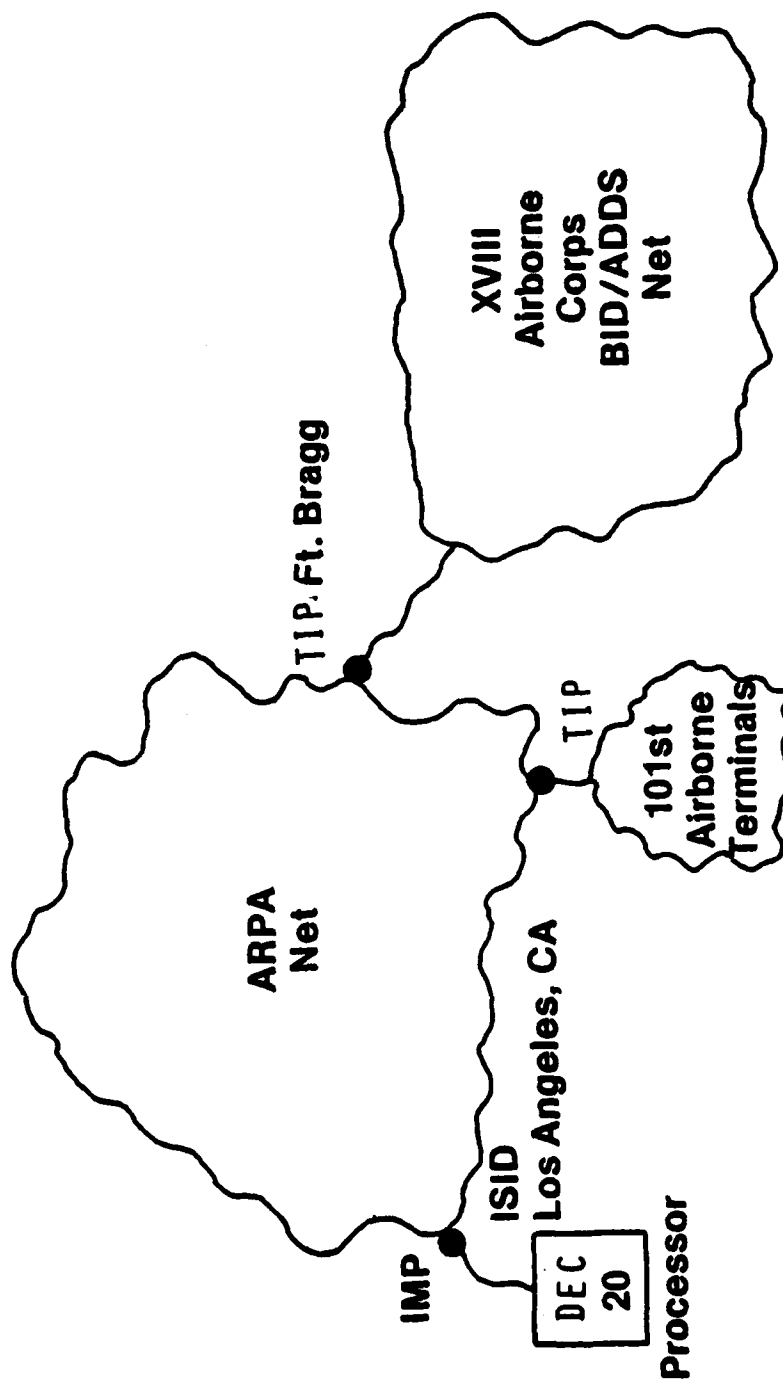
Ft. Bragg Experiment—
Distance Measures

FIGURE 10.0

19
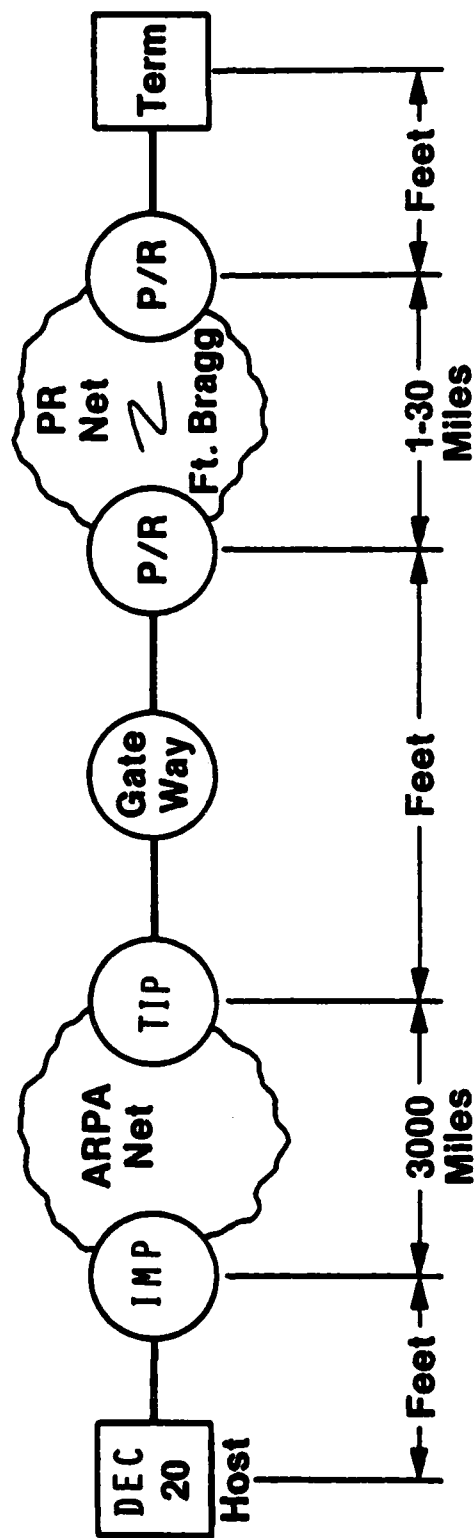
User Applications

Report Preparation/Update

Automated Aircraft Loading Program

On Line Weather

Corps Tasking

Ammunition Accounting Program

Status of Forces Agreement File

Artillery Survey

CEOI Generator

Circuit Status Program

Engineer Bridge Characteristics Program

Military Police - Convoy Status and Control

Tactical Reporting

FIGURE 11.0

List of Areas to Be Investigated

1. Corps Information Flow
2. Experimental Network Security (Interim and Long Term)
3. Closed Loop Artillery Systems Data Communications
4. Automated Aircraft Loading Program Development
5. Mobile User Network Access
6. Data Base Management and Executive Control System
7. Transition Architecture (Bids - Current C^2 Communications)
8. Distributed Tactical Processors
9. Automatic Adaptive Network Management and Control
10. Digital Voice and Facsimile
11. Network Extension and Internetting via Satcom
12. Military Oriented, Natural Language Base, Operating Software
13. Multi - Media Terminals
14. User Oriented Displays
15. Integration of ECS^2 Subordinate Systems with Experimental
    Proxy Maneuver Control
16. Expanded User Population

FIGURE 12.0

21

that the areas to be investigated in the experiment will contribute significant information that can be used by the participants to build a base of technology and associated doctrine that attacks all of the layers outlined in the generic battlefield information distribution architecture presented earlier. Areas #7 and #11 involve internet experimentation between existing communications means and developmental technology such as Packet Radio and PLRS/JTIDS Hybrid. Area #2 concerns network security issues-areas #5,6,7,8,9, and 16 are directed at various software and hardware aspects which must be examined to evolve a network management and control capability. Areas #1,#3,#4, and #15 are directed towards tactical functional mission systems. Areas #10,#12,#13,#14 have to do with aspects of the user interface layer.

The proposed five year plan is very ambitious but if all the experiment participants take full advantage of this means of developing information that can be applied to future C^3I System requirements, it will have served its purpose.

A typical example of how the experiment resources can be used in total system development is the HELBAT 8 activity planned for the fall of 1981. The Field Artillery Systems Engineering Working Group is dedicated to improving the response time of the current Field Artillery System to support tactical operations by investigating new procedures, weapons, data processing and communications technology. The HELBAT series of experiments run periodically over the past several years by the Artillery Engineering Working Group have made significant contributions to U.S. Army Field Artillery doctrine.

During HELBAT 7 (run in Feb. 1979) the driving problem area identified was the lack of efficient data distribution by radio means. This communications problem impacted the entire experiment. Therefore the priority thrust of HELBAT 8 will be devoted towards improving C^3 for the Field Artillery System.

It is projected that use of Fort Bragg Experiment resources for data distribution would reduce the communications delay significantly; from minutes to perhaps less than a second. Thus, the HELBAT executive committee has requested the participation of experiment resources in the next scheduled HELBAT exercise. This exercise is currently projected for late summer/early fall of 1981. The tentative scenario for the exercise is shown on Figure 13.0.

5.0 CONCLUSION

We have seen that connectivity and access to processing power is the key to reducing time required to move, process and act on information in a tactical operational environment.

HELBAT 8 Tentative Scenario

FIGURE 13.0

23
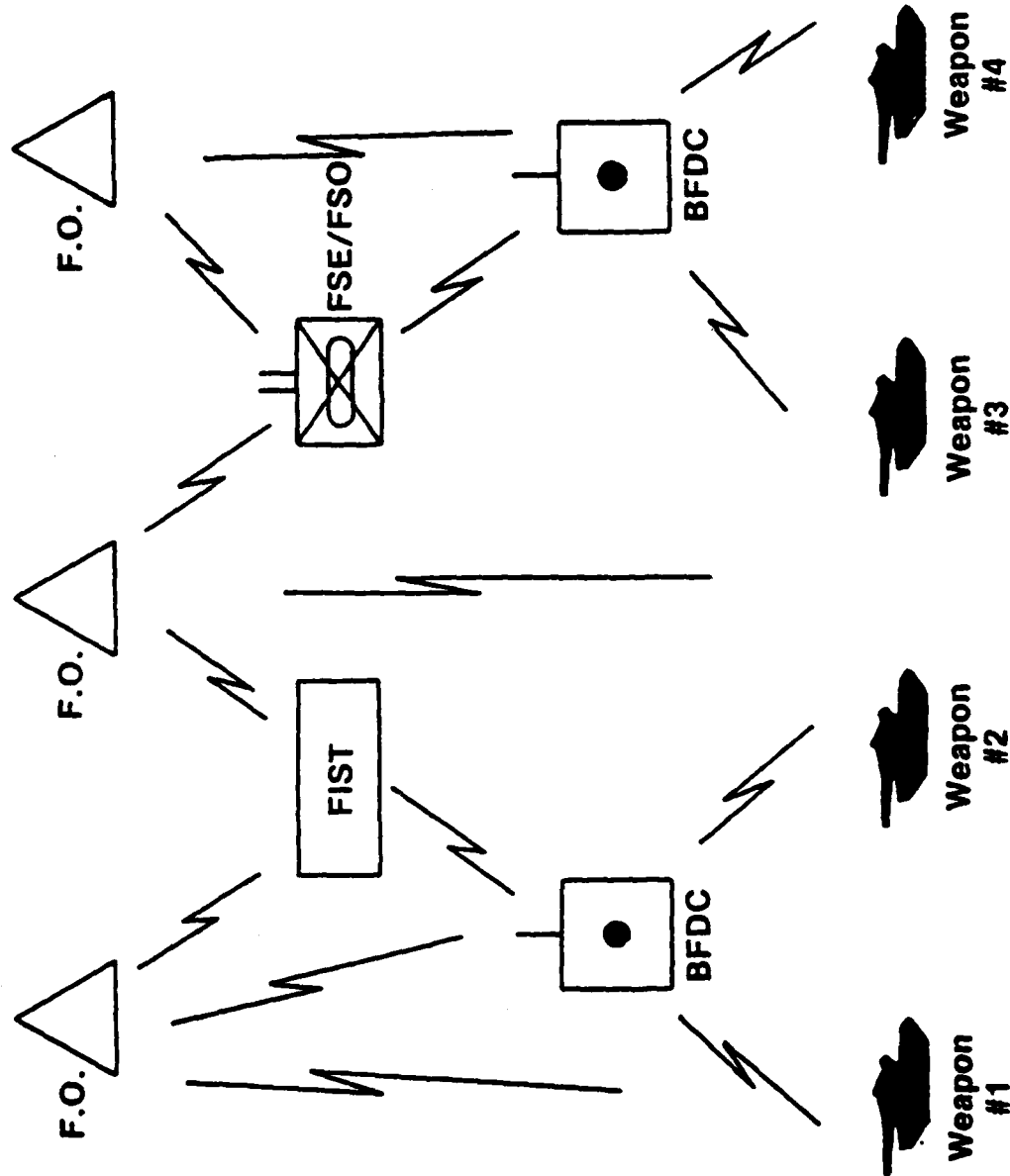
In the Army Tactical system developer environment a different kind of connectivity is required but it is equally important. If we can provide good connectivity between the user, combat development and materiél development communities so that feedback is enhanced—we should be able to reduce the time required for development as well.

However, system developers must be wary of overemphasis on technology in system design. The most essential variable in the system, the human factor, should not be ignored or left as a last consideration. The soldiers in our tactical units must be able to use the system to accomplish their assigned missions. This is why it is so important to have the soldier user directly involved with system concepts as early as possible. It is not enough just to take into account the normal human factors statistical standards which refer to human sensory motor characteristics. We need to consider such aspects as personnel turnover in tactical units, attitude towards technology, changing education levels in our troop population, time required to train individuals and cultural aspects. Of course you can attempt to simulate these things or take sample tests of the population in order to establish some norms as a basis for system validation. This kind of approach often is the only choice available to system designers. The Fort Bragg Experiment provides a better way to obtain this information. By exposing troops from all types of tactical units to developmental equipment and new concepts on a day to day basis both in garrison or while on field exercises we should get hard data which can be used in the system design. In this way many man/machine interface performance problems can be designed out in the basic system design and not left for the training community or the recruiting command to solve.

The BID/ADDS Experiment at Fort Bragg provides a framework that can be used to integrate the efforts of the R&D Community at CORADCOM, the TRADOC combat developers and the FORSCOM users in the pursuit of a C^3I System for the 1990's. The HELBAT 8 tests planned for FY81 demonstrate clearly how the experiment assets can be exploited to help develop critical doctrine.

If the key players make use of the experiment assets we just may be able to field a C3I System in the 1990's that makes use of 1980's technology. This would be in contrast to today's C^3I Systems which for the most part use technology developed in the late 50's or early 60's.

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DR. THEODORE J. KLEIN

Dr. Theodore J. Klein has been associated with communications research and development at Fort Monmouth since 1958, and presently heads the Signal Processing Division of CENCOMS. His current work includes basic and applied research and development related to information distribution systems, record communications, optical character recognition, electromagnetic propagation, and digital multiplexing projects.

Dr. Klein holds a bachelor's and a master's degree in electrical engineering from Iowa State University and Rutgers University, respectively, and a doctorate in system engineering from the Polytechnic Institute of Brooklyn.

BIOGRAPHICAL SKETCH

Frank E. Owens, LTC, USA (Retired) is currently a member of the technical staff of the C^3 Division of The MITRE Corporation, McLean, Virginia. He has served in communications electronics posts with NATO Hqs in Brussels, I Corps in Korea, 1st Sig. Bde. in Vietnam, and the Defense Communications Planning Group in Washington. He was a member of the faculty at the Army War College for a four-year tour, is a graduate of the Command and General Staff College, and holds an equivalent knowledge diploma from the Army War College.

NETWORK MANAGEMENT CONCEPTS FOR THE 1990'S AND BEYOND

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ABSTRACT

The purpose of this paper is to present some of the emerging network management concepts and techniques that could be used to provide robust, survivable, near real time digital communication for the tactical Army C^3 systems of the 1990's. In order to provide a more concrete frame work in which to examine network management, a distributed internetwork architecture is proposed. Network management functions and capabilities are then discussed in terms of the distributed internetwork architecture and of the component data distribution networks* Two examples are presented describing the potential capabilities of network management in the internet environment. Finally, a short discussion is provided that details some of the major technical network management problems that must be solved before the distributed internetwork architecture can be used in the tactical environment.

THE PROBLEM

The requirement for reliable, robust, survivable communication is fundamental to any tactical automated Army C^3 system. Approximately 250 tactical automated systems are scheduled for fielding during the 1980-1990 time frame. Each of these systems needs communication to interconnect its various subsystem components that are geographically distributed throughout the battlefield. It has been estimated[1] that several thousand users (data source or sink) in a corps area deployment may generate, correlate, assess, or act on information. The distance over which users need communication may range from several kilometers to more than 150 km. The maximum information transmission time delay permissible between some components of real time target acquisition and firing systems may be as short as several seconds. The amount of information transferred in a communication exchange may range from tens of bits to potentially hundreds of kilobits of data. The need for reliable information transmission may require as stringent a bit error rate (BER) as 10^{-12} or less for most data systems to a BER as poor as 10^{-1} or less for digitized voice.

The battlefield environment of the 1990's must be presumed to be both dynamic and hostile. Enemy forces must be expected to jam or destroy both our communication points as well as components of our tactical automated systems. Quite possibly, enemy forces could be expected to surround, cut-off, and isolate large portions of our own forces. Our own forces will likely need to be highly mobile to survive in this hostile environment. It

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* For the purpose of this paper, a data distribution network is a communication system that is characterized by integral near real time switching and data transmission. PLRS, JTIDS, PLRS/JTIDS/Hybrid and DARPA's Packet Radio are all examples of data distribution systems.

is quite evident that the future dynamic battlefield will be characterized
by a large number of connectivity changes, and thus any future data dis-
tribution system must be designed to function in that environment. The
hostile nature of the battlefield implies that functions, whether in the
automated tactical systems themselves or in the data distribution systems
that support them, must be distributed or at least decentralized in nature
so that the destruction of a single element does not lead to a loss or
collapse of the function.

A wide range of communication equipment is available and currently un-
der development. Radio based systems cover the RF spectrum from HF through
satellite to millimeter wave frequencies. Wire/cable systems range from the
familiar WD-1 field wire to megabit cable and fiber optic systems. Advanced
data distribution systems such as the PLRS/JTIDS/Hybrid (PJH) combine radio
communication using the UHF and Lx bands into an effective communication
network resource. The PJH[2] is particularly noteworthy in that it combines
real time switching and relay functions (as provided in the PLRS user units
(UU), the network control units (NCU), and the JTIDS Class II terminals) with
data transmission functions in small militarized packages. This integration
of near real time switching and transmission is made possible by the minia-
turization of computer and information processing technology. The DARPA
Packet Radio program combines even more advanced packet switching and net-
work management techniques developed in the ARPANET environment into an
early prototype of a highly mobile, robust, reliable data distribution system[3].

A DISTRIBUTED INTERNETWORK COMMUNICATION ARCHITECTURE FOR THE 1990'S

Given the need for distributed, reliable communication on the battle-
field, the problem then becomes how to effectively utilize the communication
resources the Army has at its disposal. Clearly each communication means
possesses its own advantages and disadvantages. For example, increasing
the RF center frequency of radio transmission provides the potential for both
increased bandwidth and increased mobility (through the use of smaller anten-
nas). However, increasing the RF center frequencies of broadcast radio
systems does have the unfortunate consequence of decreasing range, exhibiting
propagation characteristics similar to those of a line-of-sight channel.
Cable/fiber optic systems offer high bandwidth and excellent security, but
of course require that the cable or fiber optics be installed. Satellite
systems have the advantage of high bandwidth, but potentially could be
rendered inoperable if the satellite is destroyed or jammed.

Suppose that the data distribution principles and techniques are ap-
plied to each type of communication media. The VHF, fiber optic, satellite,
etc. nets all possess integral, near real time switching and transmission
characteristics, and are, therefore, data distribution networks. (The
channel switching and channel sensing, as part of the channel access protocol,
would normally be implemented by a small microprocessor and associated hard-
ware). To obtain the maximum advantage offered by each data distribution
system, an internetwork architecture is proposed as shown in Figure 1. This
internetwork architecture would allow direct, near real time, digital com-
munication between all users by the interconnection of the data distribution
networks through devices called gateways. Subscribers on one net would be
directly able to communicate with others on other nets automatically with
no manual intervention. The network management structure would have the
responsibility for determining on which network the destination subscriber

30

resides, select a path or paths through the internet system, and have
the full responsibility for delivery of the information or data. For ex-
ample, a single user in a tank may use a millimeter wave radio data dis-
tribution network to communicate with other tank units, but automatically
utilize a VHF-FM data distribution network when he wishes to communicate
with his commander in the rear.

A key advantage of the internetwork architecture concept is that it
allows for a total integration of communication resources. The communi-
cation resources may be managed and utilized as a whole. Consider the
problem of net partitioning due to poor connectivity between users on
the same network as shown in Figure 2. The poor connectivity may be due
to propagation effects or because relay paths were jammed or destroyed.
If each of the groups of users can communicate with another network (via
the gateway), which is in communication with both of the partitions, then
communication between the partitioned members of the network can be made.
This real time alternate routing through other networks would be under
the complete control of the overall network management.

DARPA has successfully demonstrated the feasibility of an internet-
work architecture for real time data communication in November of 1977.
In that demonstration[4] three dissimilar networks were successfully inter-
connected, and carried real time interactive traffic from the West Coast
to London. (Figure 3) Information flowed from packet radio in a mobile
van in the Packet Radio Network located at SRI International, into the
ARPANET (wire based), through the ARPANET to the NORSAR and London TIPS,
into the London gateway, back across the Atlantic Ocean via the satellite
net SATNET into the West Virginia earth station, back into the ARPANET,
and finally back to a host computer at University of Southern California,
Information Sciences Institute. While such a demonstration shows the
feasibility of near real time traffic in the internet environment, there
is still much work to be done to make this concept a practical, viable
communication system architecture for the Army of the 1990's.

NETWORK MANAGEMENT FOR THE 1990'S

The goal of network management is to provide a reliable, robust, data
distribution network for the attached user subscriber's components and
systems. The anticipated user components and systems include all types
of digital information sources and sinks, as well as terminals, computer
systems, and other digital devices. It is also possible that real time
digital speech, facsimile, and video signals could be carried by the net-
work, thus requiring a multi-node communication environment. Network
management, which is defined for the purposes of this paper as the auto-
matic decision logic that controls the behavior of the network, must be
capable of handling the wide variety of traffic requirements and must be
capable of functioning in the dynamic and hostile battlefield environment.

It should be pointed out that some form of manual network management
has always been a part of any communication network. For example, con-
ventional VHF-FM radio nets require that users be assigned to operate on
predetermined frequencies, and that relay sites be selected and set up
(if needed). Operational procedures require the use of predetermined call
signs, and Z or Q signals to increase network utilization. Other com-
munication equipment, such as multichannel and cable/fiber optic systems,

require that sites be surveyed and/or cables be installed. These well-known manual procedures for providing communication do not seem suited for the dynamic and hostile battlefield of the 1990's. The network management structure for the 1990's should free the attached user from the "burden" of using communication.

A list of potential or desired network management capabilities is provided below. This list includes network management capabilities that range from those that are quite basic and fundamental in nature to concepts that are advanced enough that they should be (and are in some cases) areas of active research. The list presupposes no specific hardware or technology implementation.

1. Fully Automatic Adaptive Network Management Operation. The network management structure should be fully capable of functioning without any manual intervention. The network management should be capable of providing total network initialization, performing net entry for new terminals entering the net, providing for reconfiguration from component failure, jamming, or destruction, as well as providing the basic assignment of communication paths to satisfy user needs and requirements. The network management should also be self organizing and adaptive to respond appropriately to dynamic connectivity changes and/or network loads without any manual intervention.

2. Survivable in the Battlefield Environment. The network management structure should be conceived, designed and implemented so that there are no controlling nodes within the system. Techniques and concepts need to be explored to manage the global control of information and associate decision logic in such a way that the loss of any element containing this information has little impact on system performance. This implies that the global information needed to control the networks must be distributed and/or stored redundantly in some manner.

3. User Transparency. The user or attached subscriber/device/system should be totally free from any details of the network operation. The user should only provide to the network the destination(s) and actual information to be transmitted and the network management structure should take care of all communication details. If desired, the user/subscriber could be notified by the network management structure that information was either successfully or not successfully delivered to the destinations. The user should be concerned only with the fact that he either is or is not in communication with the rest of the net.

4. Information Delivery Protocols. The network management structure should have complete responsibility for all phases of the information transmission process. This includes items such as address translation, in which the name supplied as the destination(s) of the information is mapped into a network address(es), transmission into the network (the net access problem), relaying and/or alternate routing (if required), and performing error checking or other reliability driven procedures as required. The network management structure should be capable of providing a range of guaranteed delivery times/or effective end to end bandwidths matched to the characteristics and needs of attached subscriber devices. For example,

32

although real time fire control messages need to be delivered within a
few seconds, some users may be satisfied with delivery times of a minute
or more. Additionally, end to end effective bit error rates of less than
10^{-12} are needed for most computer oriented traffic, but facsimile and
digital voice can utilize a much higher BER. The network management should
deliver the information to destination(s) in a manner consistent with the
subscriber requirements.

5. Internetwork Environment. The network management structure should
be capable of operating in the internet environment. The network management
algorithms should monitor the condition and status of all connected networks,
and make automatic decisions to best utilize the data distribution networks
as a whole in order to satisfy the attached subscriber needs. The network
management should fully utilize the net to net transfers possible in the inter
network environment to provide the best communication possible from the
available assets in the face of dynamic and hostile battlefield conditions.

6. Integral Position Location/Navigation/Identification. A potential
requirement exists for every user who needs to communicate to also know
his position. Additionally, some users may need to know the position of
others as a requirement for this operational mission, i.e. the Battallion
Fire Direction Center in the TACFIRE System needs to know where the for-
ward observer and firing batteries are located. Still other users may
need to be given guidance and direction to reach others, as in a rescue
mission application. It is the function of the network management struc-
ture to both compute the location of the attached subscriber, and make the
position/navigation/identification information available to all those who
need it. Identification is important in that it will allow users to properly
identify others on the battlefield and prevent accidental combat with
friendly forces.

7. Robust Network Management. The network management structure for
the 1990's should be capable of operation even when a large number (up to
50%) of communication facilities including those used to implement the net-
work management have failed, been destroyed, or jammed, or are otherwise
not in operation. If and when failures occur, the remaining active resources
should be automatically reconfigured by the network management to provide
the attached user subscriber population with the maximum communication
capabilities available.

8. Mobile Communication. The network management structure should
be capable of providing mobile communication to all units who need it as
part of their mission. This implies the network management structure must
be capable of coping with temporary changes in connectivity (such as vehicle
roll or pitch over rough terrain, or a helicopter flying behind a hill).
Data integrity and delivery protocols must be capable of providing the needed
services to users under these connectivity changes. Position location/
navigation updates must be made consistent with expected unit mobility.

9. Automatic Network Monitoring and Connectivity Enhancement.
The network management structure must clearly know the connectivity of all
units within the network in order to make intelligent routing decisions.
The network management could also keep statistics of the traffic profile
and loading through all relay and terminal subscribers, and use this in-
formation to provide near real time adaptive routing to equalize network

33

load and efficiently utilize all of the communication resources. A more advanced network structure would analyze, in near real time, the communication loading, user performance needs, the connectivity, and the constraints on availability of equipment and then recommend (if needed) that additional relays or other hardware be deployed to improve network performance. For example, the network management could recommend that additional repeaters be deployed (via helicopter, or tube launched) to improve network throughput, minimize delay, or provide additional communication capability where it appeared to the network management structure that it would be advantageous to the network as a whole. If the deployment of forces for a future military operation were properly entered into the network management structure, still more advanced network management structures could predict where communication bottlenecks might occur. Thus, the network management structure could be utilized to improve overall communication network operation and performance in near real time, during actual field combat conditions.

10. Automatic Subscriber Status Reporting. It may be useful to have some units periodically or upon demand provide their operational status to other members in the network. This information might then help the individual or element responsible for the command and control of those reporting units make more intelligent use of the available assets. For example, a mobile howitzer might automatically and periodically report its position, ammunition, and fuel status or other information to the individual or element responsible for assigning the mobile howitzer its firing missions. Then when a request for fire is received, the element responsible for assigning missions to the howitzer would know exactly the position and status of all howitzer assets, and therefore make a more intelligent decision for the assignment of resources to the mission at hand.

11. *Enhanced Addressing Schemes. Since the position and status of* all subscriber units is available to the network management structure, it is entirely possible to direct information or command and control messages to units based on their location, and/or status information rather than their network or unit address. For example, a warning might be sent to all units within a 20 mile area of location XYZ that an enemy attack was imminent. A command and control order might be addressed to all units operating 10 miles from location XYZ with a 70% or greater strength to move to a new location to stop an enemy attack or break through.

NETWORK·MANAGEMENT IN ARMY C^3

It may be instructive to show how network management capabilities may perform in two potential scenarios of Army operations in the 1990's.

The first scenario shows a distributed or cellular command post in Figure 4. The elements or cells of the command post are geographically separated to provide better survivability. Each cell contains information processing and storage capabilities, with sufficient redundancy so that the command post mission can be supported by fewer than the total number of cells. At least two different communication media are needed to support the cell to cell communications. Typically, fiber optic, millimeter wave, or VHF-UHF links would be sufficient. Communication with the command posts of adjacent units would be maintained by longer range equipment such as satellite, HF, or by a multi-hop UHF system.

34

The automatic network management structure is responsible for all cell to cell communication, as well as for communication between cells of different command posts, and to echelons higher and lower. The internetwork management would determine the connectivity between all units, and assign routes between all source/destination(s) that required communication. Connectivity would be constantly monitored to provide new real time routing information for cells that have moved, failed, or have been jammed or destroyed. The operational status of all cells would be available to the other cells that need that information, so C^2 decisions may be made with the latest reliable information available.

The network would have the responsibility for determining whether a cell had been destroyed or was temporarily out of communication due to failure or enemy jamming. Most likely the enemy would not be capable of simultaneously jamming the two or more communication links interconnecting the cells. If a cell were being effectively jammed, the network would automatically deliver traffic to that cell via the alternative communication means. If the cell were declared destroyed, its function would be automatically transferred to one or more still active cells. Messages or information destined for the destroyed cell would be automatically routed to the new cell(s) which had taken over the destroyed cell(s) function. Of course, any unique information that the destroyed cell contained would be lost, but this effect can be minimized by enabling all cells to have access to all information that is absolutely critical to the conduct of the battle.

Another technique that could be used to increase the survivability of the command post would be to utilize an information storage capability similar to that provided by the ARPANET - host electronic mail scheme. Under this technique, in addition to delivering the critical information to its desired destination(s), the network management structure would automatically deliver copies of critical battlefield information to several "host like" machines for temporary storage located either in "Sanctuary" or in a remote area of the battlefield. Then if a particular cell or critical element failed or was destroyed, the network management structure could then automatically reconstruct a large part of the destroyed/failed cells data from the "host like" machine. At periodic intervals the temporary storage machines would be purged to make room for additional new battle field information. This technique could also be used to temporarily store information for cells that were temporarily out of action due to failure or communication blackout. Upon reentering the internetwork communication environment, and during the reinitialization of the cell in the internetwork management structure, the network management structure would automatically query the temporary storage machine for recent information received while the cell was unable to receive information destined for it, and deliver the information back to the cell. The network management structure could also indicate to other cells that the cell in question is now back in operation.

A real time fire control scenario is provided as a second example. Real time fire control systems, such as those of the Field Artillery[5] and Air Defense communities, are characterized by the need for high bandwidth, low delay (source to sink(s), robust communication over potentially long distances, and may require a significant multi-destination addressing/routing capability to support their command and control functions.

Any fire control system is functionally composed of three types of elements: the sensors, which have the mission of locating and tracking targets; the shooters, which actually fire weapons to destroy targets; and the decision makers, which must correlate and process information from the sensors, and assign shooters to specific missions or targets. Due to the speed of battle, the time between target acquisition/tracking by sensors and the time that the shooters fire at the target should be kept to a minimum to yield a high probability of destroying the target.

The network management structure would provide needed near real-time data distribution for the fire control systems as shown in Figure 5. The network management structure would use the internet environment to set up duplicate routes between critical subscriber devices to insure that the stringent time delay requirements would be met, even if intermediate relay points were jammed or destroyed. Reliable end to end protocols would insure that only one copy of an input message or data segment was delivered to the appropriate destination(s). Position location information and operational status information concerning the sensors and shooters would be constantly transmitted in near real time to the decision makers, so that any mission assignment could be based on the latest accurate information. Position location and operational status information could be sent to several designated decision makers, so that if one decision maker were incapacitated the sensor and shooter assets that were under his command and control would be instantly (within seconds) available for use by other decision makers remaining operational. The network management structure would also support dynamic reconfiguration of sensor/shooter resources to provide their maximum utilization for critical missions by reassignment of the appropriate routes/relay points in near real time. For example, after proper coordination and control, several shooters and sensors, not normally associated with a given decision maker, could be temporarily loaned to him for the execution of a critical mission. The required communication paths would be automatically reconfigured to provide the needed communication capability in near real time. At the completion of the critical mission, the communication paths would revert back to their previous configuration, and the sensors and shooters would be automatically restored to their former decision makers.

CURRENT STATUS OF THE DISTRIBUTED INTERNET CONCEPT

The preceding paragraphs have provided a glimpse into the capabilities of future network management concepts of data distribution networks for the automated tactical C^3 systems of the 1990's. Many unsolved problems, however, still remain. For example, although DARPA has successfully demonstrated the internetwork concept, there are many technical aspects concerning net access, addressing, gateway to gateway routing, congestion and flow control that remain the subject of active research. Specifically, how and when should adaptive routing be used between networks? Should an internet

subscriber designate a network address or a gateway address in the internet
routing procedures? How can a partitioned network use the internet concept
to establish and maintain communication between the partitioned pieces?
Reference 6 presents an excellent summary of the ongoing internet efforts
and provides a comprehensive list of research questions which need to be
solved. Even within a single network, the degree to which the network
management itself can and should be distributed is not yet a solved problem.
For example, if fully distributed control is not practical for techni-
cal or operational reasons, then how should the control of the network be
implemented? One and two or more level hierarchies have been proposed,
but many "loose ends" remain. How should the coordination be handled with-
in a given hierarchy? By what mechanism and how often should information
within a hierarchical level be exchanged or updated? How should reconfig-
uration both within and without a hierarchical level be implemented? Re-
ference 4 provides some insight into the distributed control concepts for
the DARPA Packet Radio Network, while reference 7 addresses the problem
in more general terms.

Much work also needs to be done in the area of distributed adaptive
routing for large networks. Although distributed adaptive routing techniques
have many advantages over centralized routing procedures, it appears as though
the control overhead and/or time to reach steady state (often connectivity
change) grows as the square of the number of devices participating in the
routing decision.[8] This squared factor may effectively limit the size of
the network (or subnetwork) in which the distributed algorithms may be
utilized. Additionally, while much work has been done for distributed,
adaptive routing algorithms, and for centralized routing algorithms, very
little research has been performed on routing techniques which could effect-
ively utilize a multi-level hierarchical network management structure.

In the area of delivery protocols, great strides have been made by the
development of the Transmission Control Protocol (TCP)[9] and associated Inter-
net Datagram Protocol for the near real time, internet environment. But
these protocols are primarily oriented toward one to one, process to process
communication. The area of reliable, robust, efficient delivery protocols
for the multi-destination internet environment, still needs much research,
although Dr. Pardo[10] has made some noteworthy progress in this area.

CONCLUSIONS

This paper has presented some network management concepts that could
be used by data distribution networks that may serve the automated tactical
C^3 systems in the 1990's. The network management concepts need to take
full account of the battlefield environment in which they must operate to
provide robust, reliable and survivable communications for the attached sub-
scriber systems. The distributed internetwork architecture seems to be
capable of satisfying this need. By integrating all the communication re-
sources on the battlefield in an internetwork architecture, a more reliable
and survivable communication facility may be provided. While the network
management structure needed to manage and control the internet architecture
is still in its infancy, some of the more highly developed concepts and
techniques may be applied to evolving systems, such as the PJH, so that the
final integration in the internet environment may prove easier. The current

37

state of the art, however, shows that there is much work to be done to pro-
vide the robust, reliable, network management for the internet environment.

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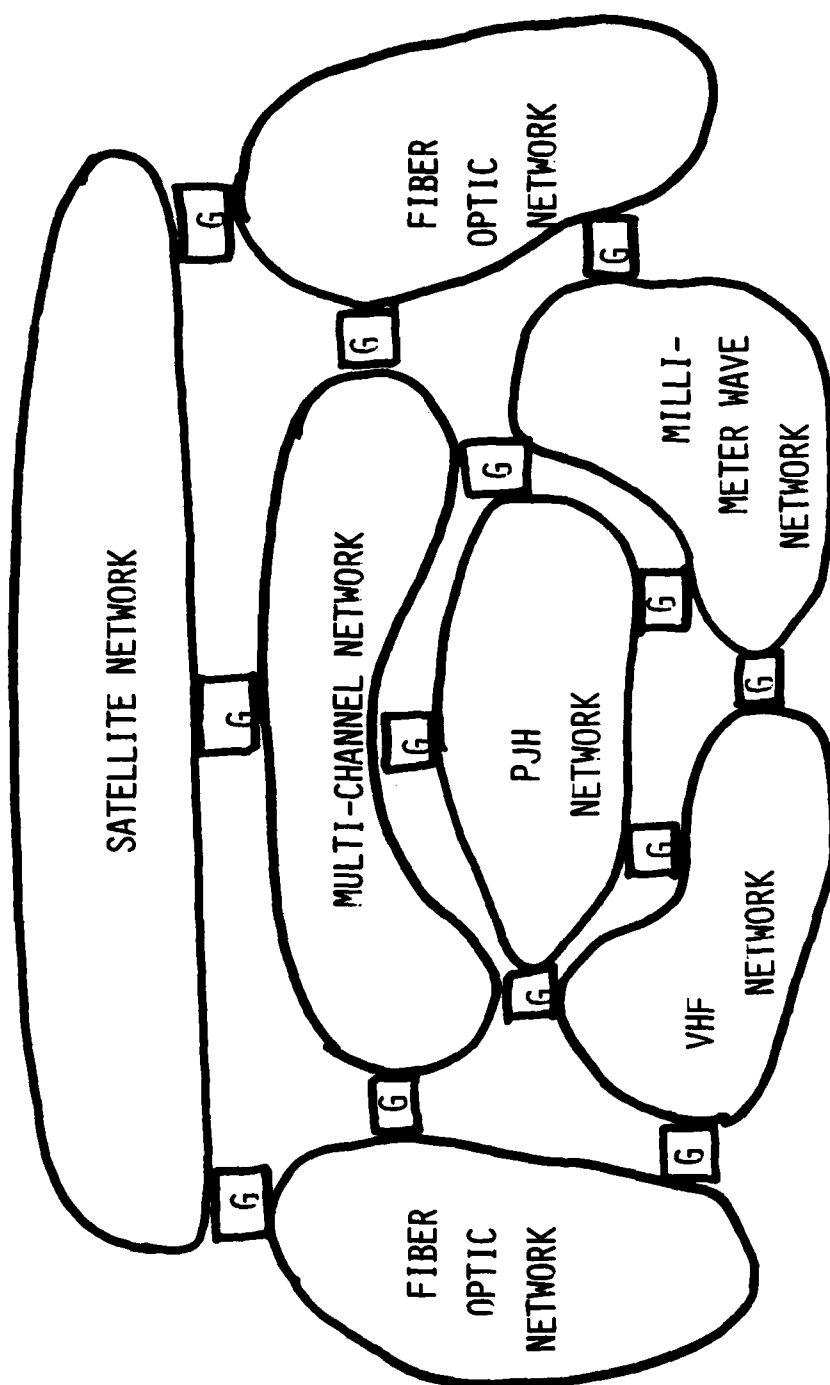
- EACH NETWORK IS A DATA DISTRIBUTION NETWORK
- NETWORKS ARE INTERCONNECTED BY GATEWAYS G
- DISTRIBUTED NETWORK MANAGEMENT CONTROLS ENTIRE DISTRIBUTED INTERNET ARCHITECTURE AND EACH DATA DISTRIBUTION NETWORK

FIGURE 1.   THE DISTRIBUTED INTERNET ARCHITECTURE

40
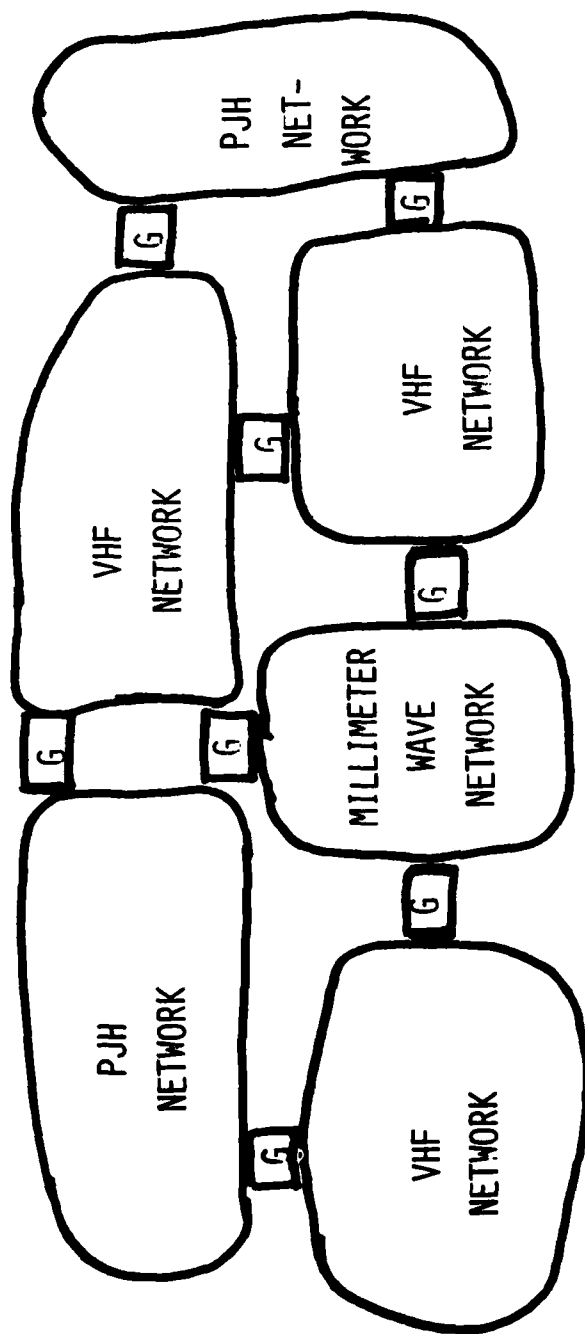
- NET TO NET CONNECTIVITY, AND CONNECTIVITY WITHIN EACH NET IS
  CONSTANTLY MONITORED BY NETWORK MANAGEMENT
- IF NET PARTITIONING OCCURS DUE TO FAILURE/DESTRUCTION/JAMMING OF
  RELAY POINTS, NETWORK MANAGEMENT AUTOMATICALLY PROVIDES COMMUNICATION
  VIA INTERNET ARCHITECTURE.

PJH NET-WORK

VHF NETWORK

VHF NETWORK

MILLIMETER WAVE NETWORK

PJH NETWORK

VHF NETWORK

FIGURE 2. INTERNETWORK COMMUNICATION SOLVES NET PARTITIONING PROBLEM

41

NORWEGIAN DEFENSE
RESEARCH ESTABLISHMENT
KJELLER, NORWAY

NORSAR
TIP

LONDON TIP

ARPANET

INTELSAT
IV-A

TANUM, SWEDEN
EARTH STATION

ETAM, WEST VIRGINIA
EARTH STATION

UNIVERSITY COLLEGE LONDON
LONDON, ENGLAND

GOONHILLY DOWNS,
ENGLAND
EARTH STATION

ATLANTIC PACKET
SATELLITE NET

UNIVERSITY OF SOUTHERN CALIFORNIA
INFORMATION SCIENCES INSTITUTE
MARINA DEL REY, CALIFORNIA

BOLT BERANEK AND NEWMAN
CAMBRIDGE, MASSACHUSETTS

ISI-C

SAN FRANCISCO BAY AREA
PACKET RADIO NET

SRI

PACKET
RADIO NET

SRI
VAN

SRI
MENLO PARK,
CALIFORNIA

LEGEND

(R) PACKET RADIO REPEATER
(I) ARPANET IMP
(T) ARPANET TIP
(S) SATELLITE IMP
[G] INTERNETWORK GATEWAY
[S/G] PACKET RADIO STATION
INTERNETWORK GATEWAY
········· PATH OF PACKETS

FIGRUE 3 THE DARPA INTERNET DEMONSTRATION

42
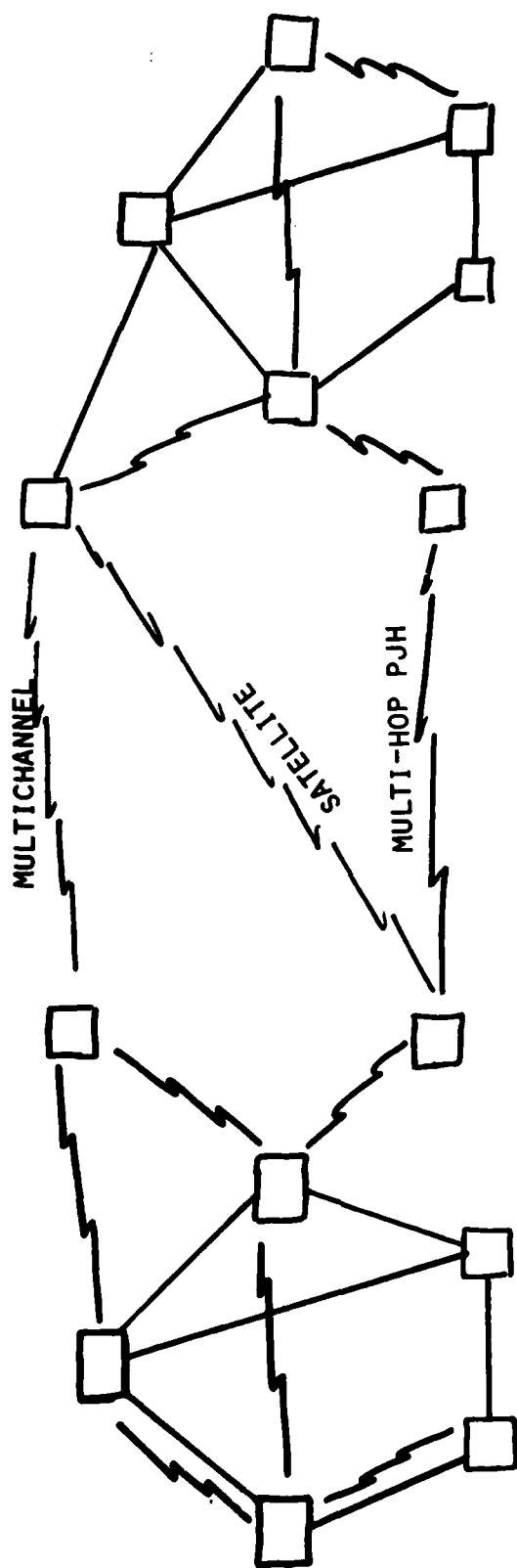
- EACH CELL OF CP HAS PROCESSOR & MEMORY
- EACH CELL IS CONNECTED TO OTHER CELLS IN CP BY AT LEAST TWO COMMO MEANS
- LONGER RANGE COMMO MAINTAINS CP TO CP COMMO
- NETWORK MANAGEMENT PROVIDES ROUTING & NET TO NET COMMUNICATION PATHS AS REQUIRED BETWEEN CELLS WITHIN A CP & FOR CP TO CP COMMUNICATION

FIGURE 4. DISTRIBUTED OR CELLULAR CP CONCEPT

MULTICHANNEL

SATELLITE

MULTI-HOP PJH

43
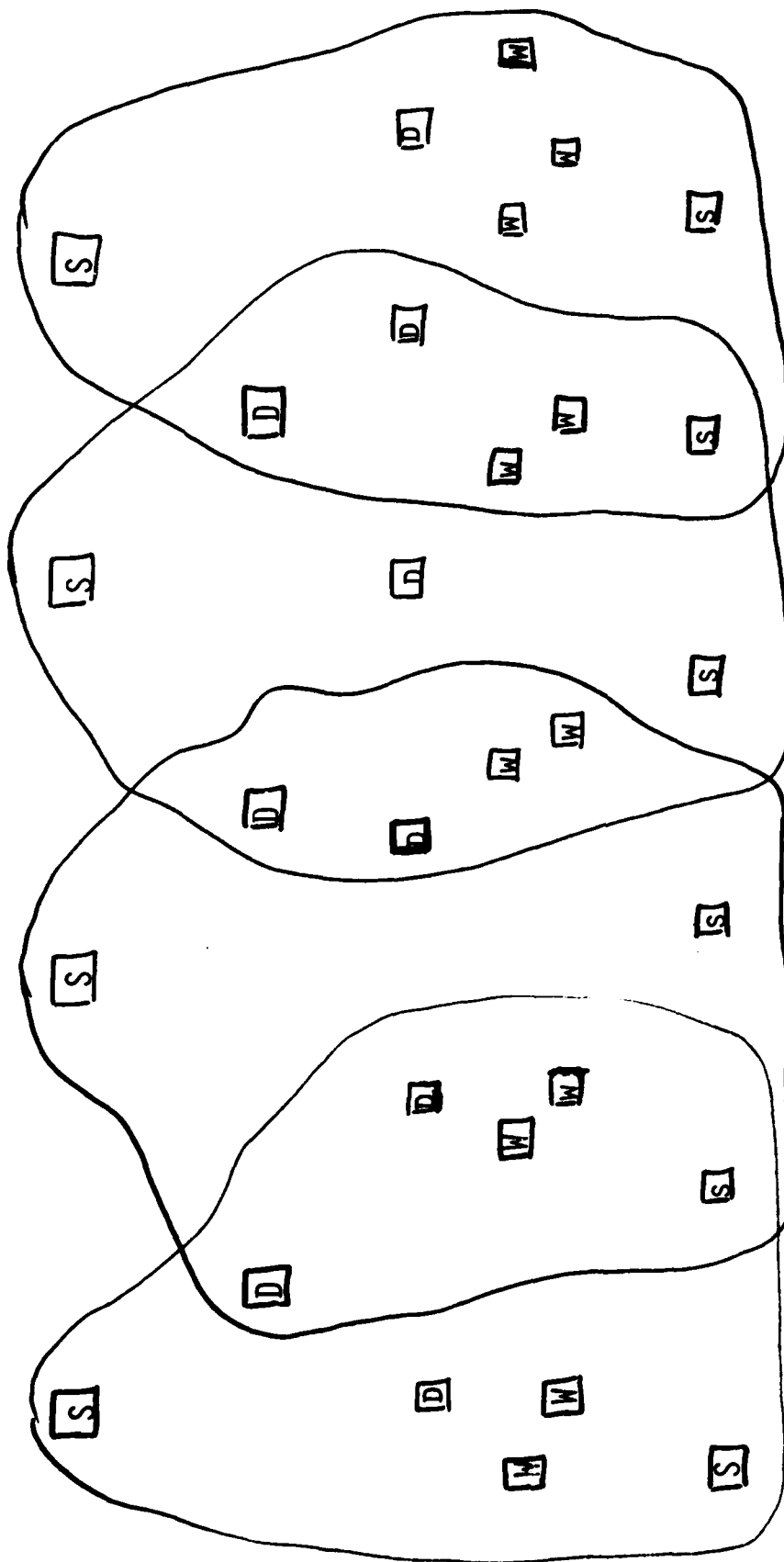
S – SENSOR   D – DECISION MAKER   W – WEAPON

- NETWORK MANAGEMENT WILL PROVIDE NEAR REAL TIME INTERNET DATA DISTRIBUTION
- NETWORK MANAGEMENT WILL SUPPORT REAL TIME RECONFIGURATION OF SENSORS, DECISION MAKERS, & WEAPONS TO SPECIAL MISSION REQUIREMENTS

FIGURE 5. DISTRIBUTED INTERNET ARCHITECTURE FOR REAL TIME FIRE CONTROL SYSTEMS

MR. CHARLES J. GRAFF

Mr. Graff earned his BSEE and MSEE degrees from Drexel University in 1969 and 1972, respectively. He received his MS degree in Computer Science from Fairleigh Dickinson University in 1976 and is currently enrolled in the Computer Science Doctoral program at Stevens Institute of Technology.

Since 1976, Mr. Graff has been a member of the Advanced Communication Technology Team for the Communications Systems Center of CORADCOM. In this particular position, he has been involved in all technical aspects of the emerging technology of data distribution systems, with specific emphasis on network management. Mr. Graff has published a paper on packet radio network protocols that was also presented at the First Annual Army Software Symposium in May of 1977. He is the co-author of a paper entitled " A Packet Radio Communication System Architecture in a Mixed Traffic and Dynamic Environment," which will be presented at the 1980 Computer Networking Symposium, to be held in December of this year.

TACTICAL SATELLITE COMMUNICATIONS
AND CONTROL FOR THE FUTURE

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INTRODUCTION

A practical and reliable communication is a recognizable need for the success of any military or civilian task. In recent years, communication thru satellite has established itself as a relatively inexpensive, viable means of communication, especially when factors such as range, terrain, and operational requirements are considered.

The US Army through its Ground Mobile Forces Satellite Communications (GMFSC) Program, has committed itself to provide practical and reliable satellite communications to those components of the Army, Marine Corps and Air Force engaged in land combat operations.

In the overall concept, the GMF satellite communications will augment or replace communication links or connectivities, which until now, were provided by conventional systems. It should be stressed, that the conventional systems, such as: line-of-sight (LOS) radio relay, tropo scatter, or high frequency single sideband radios will not be completely supplanted, but alternately will be employed if conditions, or more simply convenience and availability dictate their use. However, the introduction of the satellite communication capability, as has already been field proven, will significantly improve command and control communications.

ADVANTAGES AND DISADVANTAGES OF SATELLITE COMMUNICATIONS

Satellite communication is well recognized for its advantages over the terrestrial system. It overcomes limitations, and solves some of the problems intrinsic in the terrestial systems. For example, the satellite communications offer:

a. Freedom from siting restrictions. The terminals do not require prominent terrain, special sites or special preparation of sites for deployment.

b. Greatly extended communications range, without the use of relays. A range of up to 9000 miles is not unusual.

c. High mobility and rapid emplacement. A terminal can become operational within one half hour of arrival on site.

d. Relative immunity from signal propagation problems.

The disadvantages, although not many, none-the-less, still exist. They are inherent and unique to the system, rather than the mode of operation. For example:

a. The number of terminals which can access any one satellite is heavily dependent on the satellite transponder capacity and the antenna configuration.

b. Problems related with jamming.

THE SPACE SEGMENT

Military satellites used by GMF are in synchronous orbit, and are positioned for worldwide coverage.

47

The GMF Satellite Communications System which is currently entering service, is the Super High Frequency (SHF), Multichannel, full duplex, high data rate, terminal complement designated as AN/TSC-85 and AN/TSC-93. It operates through the Defense Satellite Communications System (DSCS II) satellite.

The DSCS II satellites are in synchronous orbit, and are positioned to provide worldwide coverage. The earth coverage consists roughly of four (4) regions: Atlantic Ocean, Indian Ocean, West Pacific and East Pacific. Each region has its own active satellites. The regions may overlap, such that, for example, an AN/TSC-85 terminal located in Europe may be able to access either the Atlantic Ocean or the Indian Ocean satellite. Each satellite is spin-stabilized with the payload of communication electronics mounted on a despun platform, which is always pointed to earth. Two steerable antennas are provided, one narrow coverage and one area coverage. The narrow coverage antenna illuminates approximately 900 miles diameter footprint on the surface of the earth. The area coverage illuminates somewhat larger footprint.

In addition, two earth coverage antennas are available. The earth coverage antennas are cross-coupled with the narrow and area coverage antennas, thus allowing the signals to be transmitted or received through any antenna combination. For example, communications may be received by an earth coverage antenna and transmitted by a narrow or area coverage antenna or vice versa.

The wide-bandwidth, low distortion repeater in the satellite enables multiple carrier frequency division and spread sprectrum multiple access for transmission of voice and digital data. The repeater is capable of linear, quasilinear and hard limiting operation. Gain adjustments can be commanded from earth. Figure 1 shows the cross section view of the DSCS II satellite, and Figure 2 shows the operational frequency plan for the DSCS II.

SYSTEM CONCEPT

The intermediate development of SHF multichannel tactical satellite communication terminals, which meet full military specifications, has been finalized.

The terminals are in truck-mounted configurations, emphasizing quick reaction and operational flexibility. The basic differences between the two terminal types are in the areas of baseband multiplex equipment, subsystem redundancy, and in the nodal and non-nodal capabilities. The nodal function provides for one terminal to simultaneously support full duplex multichannel links to as many as four widely dispersed destinations. The concept is visualized in Figure 3, which shows a nodal terminal at Corps linking four (4) Divisions in a typical field connectivity. The nodal terminal transmits a combined digital stream of up to 96 full duplex voice/data channels on a single RF carrier; twenty-four channels per each Division destination. Each one destination decombines its particular group of 24 channels and consequently releases them to users. On the return path, each of the four Division destinations transmit their particular 24 channels to the nodal station on a uniquely assigned transmit frequency carrier. These four carriers are received separately, demodulated and decombined by the nodal terminal. The digital combining and decombining process avoids the need for multicarrier operation and the attendant intermodulation problems.

The need for the different terminal configurations of varied capabilities is derived from the different user needs.

The control of the system is accomplished through a Network Control Terminal (NCT), designated as AN/MSQ-114. The NCT is equipped with an Automatic Communications Monitor (ACM), which monitors the repeater output in frequency and amplitude and gathers data for each signal access. With this data, supplemented by Network Terminal status and link performance information from the user networks, the ACM can compute the conditions necessary to maintain the system power balance and repeater operating point. The NCT can provide control communications for up to 50 network terminals.

TERMINAL DESCRIPTION

NODAL TERMINAL AN/TSC-85

This terminal is a multipoint, trunking terminal; transmitting a single multiplexed, high data rate carrier and receiving from one to four independent carrier frequencies. The electronic equipment is contained in a S-250 shelter which in turn is mounted on a W-300 truck. A companion power trailer (PU-619/G Modified) is used for stowage of antenna parts and other assemblage items during transport. When operational, the power trailer provides 115 VAC primary power source from its generator unit. The AN/TSC-85 terminal is shown in Figure 4.

48

During terminal deployment, the antenna is ground mounted on a special double tripod frame structure to help maintain antenna pointing on the satellite during various wind loading conditions. The antenna group consists of an 8 foot parabolic reflector with the feed and antenna mounted electronics, and the elevation and cross-elevation drives. The drives are activated by the antenna Servo Control Unit (SCU). Satellite tracking is accomplished by a random step scan using the received communications signal as the source which provides signals for the SCU which is driving the linear actuators.

The terminal contains a Tactical Satellite Signal Processor (TSSP) for combining of up to four (4) data streams into a single high data rate stream of up to 96 channels of PCM. This combined data stream feeds the digital modem which impresses the data onto a 70 MHz carrier using differential encoded PSK modulation. The 70 MHz signal in turn, is translated to the SHF frequency transmit band by an Upconverter Unit and amplified by the High Power Amplifier (HPA) prior to transmission to the satellite by the antenna. The Upconverter unit contains a frequency synthesizer which permits frequency selection in 100 KHz steps across the transmit band from 7.9 GHz to 8.4 GHz.

In the receive portion of the terminal a redundant low noise parametric amplifier provides a maximum system noise temperature of $300^{0}K$ in conjunction with the remaining portions of the receiver. Four (4) Downconverter units are used for reception of the four independent FDMS signals.

Frequency synthesizer units are used in the SHF receive band of 7.25 GHz to 7.75 GHz. As in the upconverter, frequency selection is provided in 100 KHz steps. The four (4) down-converted signals interface with four (4) digital modems which extract the data streams and furnish them to the receive section of the TSSP. The TSSP provides the appropriate level shifts and sends the four data streams to the Mux Van for proper demultiplexing and D/A conversion to the voice frequency band.

NON-NODAL TERMINAL AN/TSC-93

This terminal is a non-nodal or a point-to-point terminal, capable of transmitting and receiving on a single carrier 6/12/24 channels of voice frequency or data signals. Extensive tradeoff analysisemphasizing a self-contained terminal and still conforming to tactical weight and size limitations have dictated elimination of redundancy in this terminal. The electronic equipment is housed within a S-250 shelter and mounted for transport on a W-300 truck. Power trailer is the same as that used by the AN/TSC-85. Entry for 24 voice channels is provided and selection of digital or analog operation is made on a channel basis. The antenna and the terminal operation is similar to the AN/TSC-85.

The terminals require less than 30 minutes to be placed into full operation by a four man crew after arrival at an operating site, even in adverse weather conditions.

The mean-time-between failure exceeds 850 hours for a single string configuration, and the maximum-time-to-repair can be accomplished within one hour at 95% of the time. The electrical and mechanical design has been based on a expected useful life of 15 years.

FUTURE TRENDS

At this time, almost all of the military satellite communication networks have been designed to operate via a relatively simple satellite transponder. Namely, a signal is received, enhanced, and retransmitted back to earth. The future satellite communication networks are likely to strive for improvements in such parameters as flexible connectivity among user terminals, greater efficiency in utilization of satellite power and bandwidth, and resistance to interference. In achieving these objectives satellite on-board processing will be used. That, together with appropriate combinations of ground terminal capabilities such as PM TDMA, DAMA and Coding will offer a real potential for increased effectiveness of the tactical satellite terminals. The ground terminals themselves are also subject to improvement, with the trend going to utilizing higher frequency bands for transmission, and improved antenna designs such as electronically steerable phased arrays. This may well result in greatly improved reliability as well as much quicker setup and tear-down times, lighter weight, and of course greater mobility.

To this end, the US Army Satellite Communications Agency is currently investigating a satellite terminal system characterized as Multichannel Objective System (MCOS). The MCOS will succeed the current system during the 1990's. It will provide highly efficient utilization of satellite capability and will permit flexible routing of switched traffic throughout the TRI-TAC network.

49

CONCLUSION

The satellite communication terminals described, have proven highly successful in the system evaluation test programs and the limited operational deployment exercises, where they have been utilized extensively. Deployment of the production units currently scheduled for the early 80's and featuring a number of improvements over the existing models, will provide the users with a long sought after communications capability.

ABOUT THE AUTHOR

Mr. Stephen F. Rurak (BSEE, MSEE, MBA) is an Electronics Engineer currently with the Systems Development Office, US Army Satellite Communications Agency, Fort Monmouth, NJ. In that capacity he performs system analysis, optimization, and frequency planning for satellite communications. Prior to joining USASATCOMA in 1974, Mr. Rurak worked in Combat Surveillance and Target Acquisition Laboratory of the Army Electronics Command, Fort Monmouth, NJ.
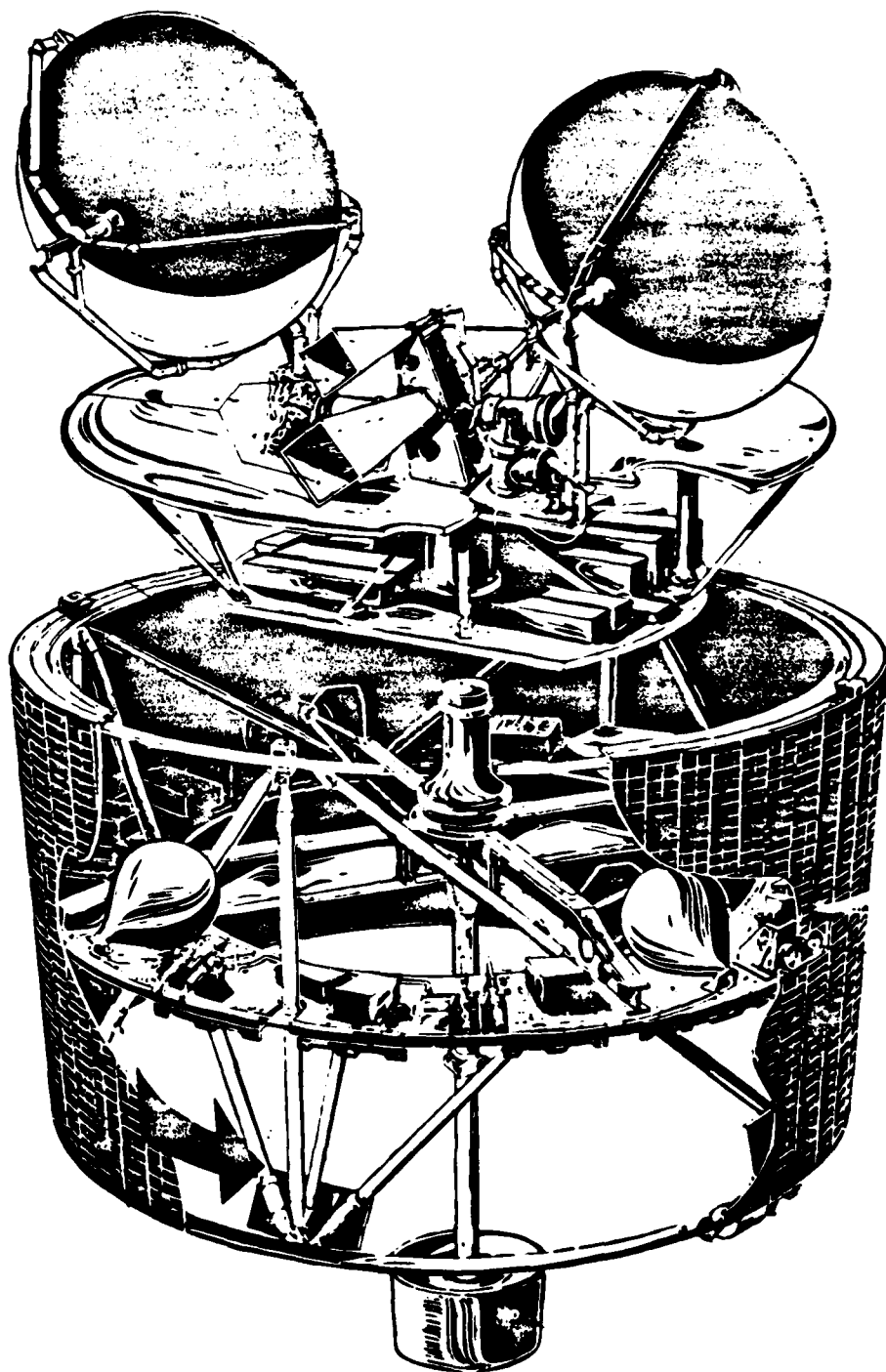
FIGURE 1
DSCS II SATELLITE

51

FREQUENCY PLAN

RECEIVE FREQUENCIES (MHz)

NARROW COVERAGE RECEIVE

EARTH COVERAGE RECEIVE

7900 7950 7975 8100 8125 8175 8215 8400

CHANNEL 3 185 MHz

CHANNEL 4 50 MHz

7675.1

NC BEACON

7675 7700 7750

CHANNEL 1 125 MHz

CHANNEL 2 50 MHz

7375 7400 7450 7490

EC BEACON

7250.1

7250

TRANSMIT FREQUENCIES (MHz)

NARROW COVERAGE TRANSMIT

EARTH COVERAGE TRANSMIT

FIGURE 2

52

SATELLITE: DSCS II

ORDERWIRE

AN/TSC-93

AN/TSC-93

AN/TSC-93

AN/TSC-93
SPOKE TERMINAL

(1) MULTICHANNEL LINK

(4) MULTICHANNEL LINKS

AN/TSC-85
HUB TERMINAL

AN/MSQ-114
CENTRAL CONTROL
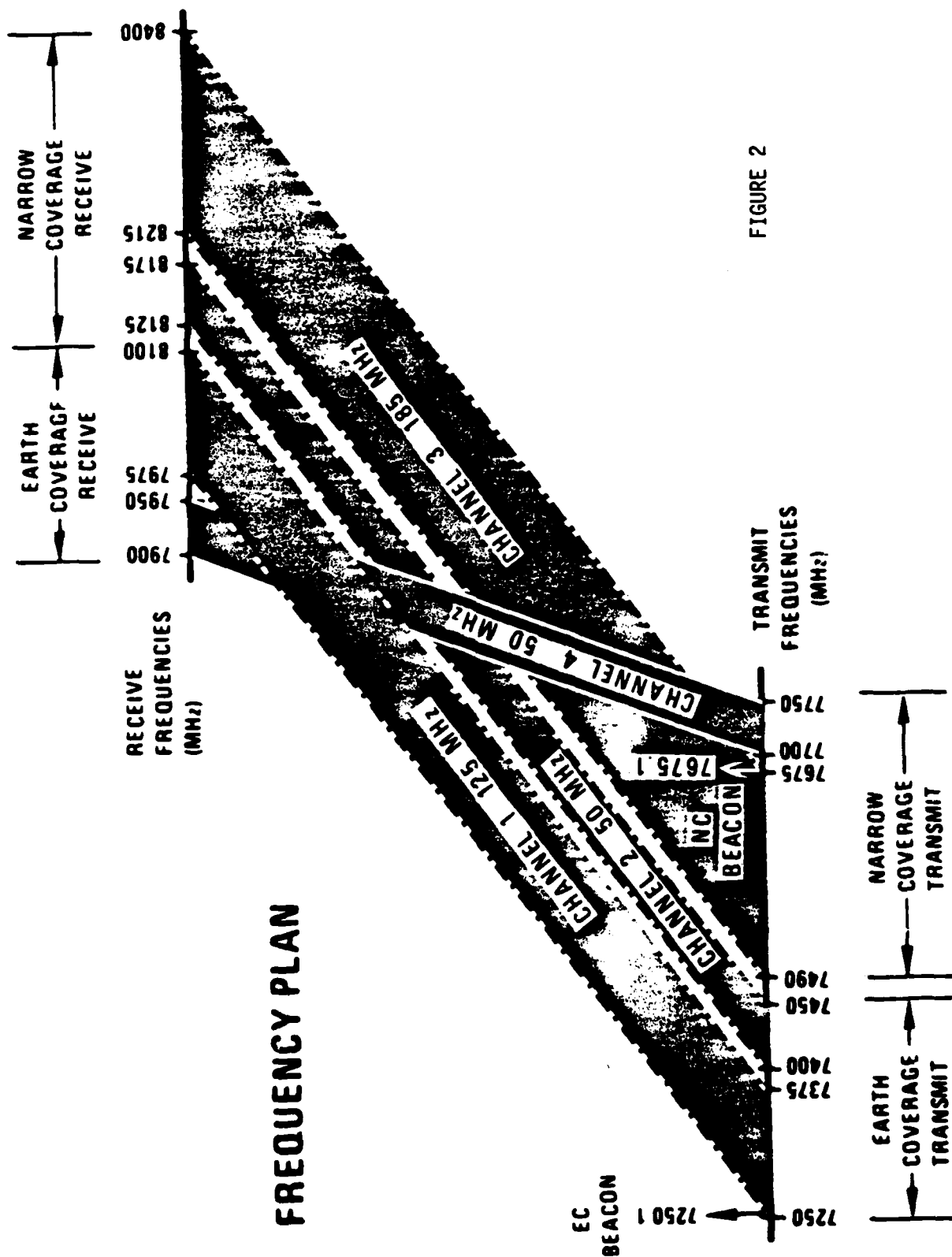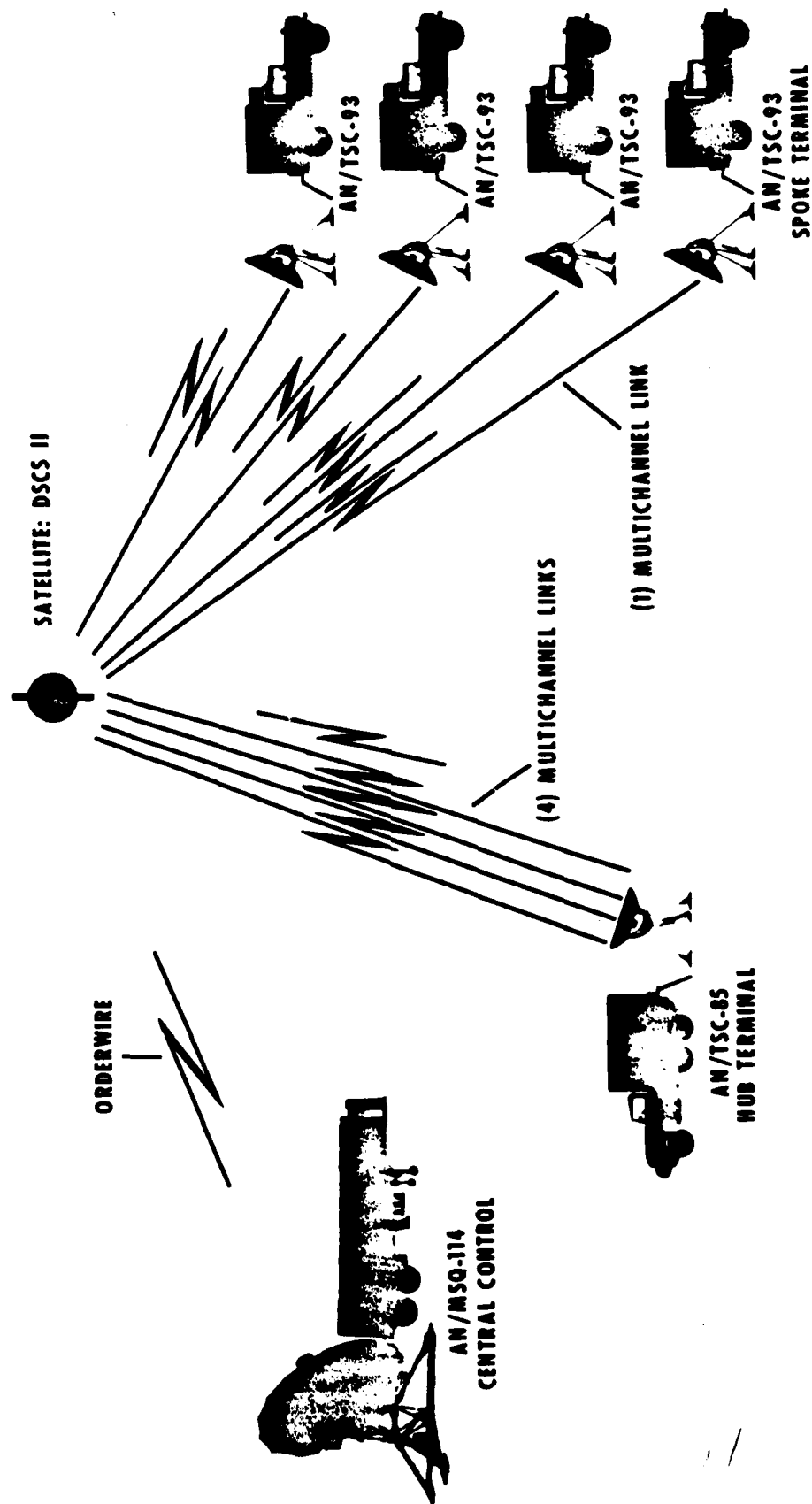
FIGURE 3.
SYSTEM CONCEPT

53

FIGURE 4
AN/TSC-85

AFCEA
BAA V PRESENTATION

21-22 OCT 80
FT MONMOUTH, NJ

PRESENTED BY
LTC JAMES E. GLEASON
CH, ARMY C^2/JINTACCS DIV
C^{3}I DIRECTORATE, CACDA
FT LEAVENWORTH, KS

AFCEA

BAA V PRESENTATION

GOOD AFTERNOON, I AM _____ OF THE COMBINED ARMS   BLANK

COMBAT DEVELOPMENT ACTIVITY AT FORT LEAVENWORTH, KANSAS. TODAY
I WOULD LIKE TO GIVE YOU A SHORT PRESENTATION OF THE EXECUTIVE
CONTROL & SUBORDINATE SYSTEM CONCEPT OF ECS^2 WHICH FORMED THE

BAA V
NOTEBOOK

CORNER STONE OF THE FIFTH IN A SERIES OF GENERAL OFFICER FORUMS   BLANK
KNOWN AS THE FIFTH BATTLEFIELD AUTOMATION APPRAISAL OR BAA V.
THIS APPRAISAL WAS HOSTED BY THE ARMY COMMUNICATIONS COMMAND AT
FORT HUACHUCA, 29-31 JULY.

TAPR

1976

BEFORE WE GET INTO THE ECS^2 CONCEPT AND THE RESULTS OF THE BAA V, THEME
LET'S TAKE A BRIEF LOOK AT THE EVOLUTION OF THE AUTOMATION CONFERENCES.   THEME
THESE CONFERENCES HAD THEIR ORIGIN BACK IN 1976 WHEN THE CHIEF OF STAFF
DIRECTED THAT WE CONDUCT WHAT WAS AT THAT TIME REFERRED TO AS A
TACTICAL AUTOMATION PROGRAM REVIEW.

A MANAGEMENT PROBLEM THAT
NEEDS A MANAGEMENT SOLUTION.

THE THEME FOR THIS REVIEW WAS SUPPOSED TO BE AS SHOWN. HOWEVER

TAA I

1976

FT MONROE, VA

PAUSE

AT THE LAST MINUTE THIS REVIEW WAS CANCELLED AND LATER ON THAT
YEAR THE FIRST TACTICAL AUTOMATION APPRAISAL OR TAA I WAS HELD
AT HQ TRADOC AND FOCUSED ON THESE ISSUES.

TAA I ISSUES

- EARLY FIELDING OF TOS
- CORPS LEVEL AUTOMATION
- CONCEPT FOR EAC
- COMMUNICATIONS FOR TACTICAL AUTOMATED SYSTEMS
- INTERFACE OF TRADOC/DARCOM WITH NSA

TAA II

1977

FT HOOD, TX

PAUSE

TAA II WAS CONDUCTED THE FOLLOWING YEAR AND FOR THE PURPOSE SHOWN
HERE.

PAUSE

TAA II
PURPOSE

HIGHLIGHT/REVIEW PROGRESS BEING MADE BY
THE ARMY IN ITS MAJOR TACTICAL AUTO-
MATION PROGRAMS SINCE 12 JULY 76.

BAA III

1978

FT GORDON, GA

IT WAS NOT UNTIL 1978 THAT WE BEGAN TO CALL OUR APPRAISALS BATTLEFIELD AUTOMATION APPRAISALS WHEN BAA III WAS HOSTED BY FORT GORDON, GEORGIA, FOR THE PURPOSE SHOWN HERE.

PAUSE

ASSESS MANAGEMENT PROGRESS BEING MADE BY THE ARMY IN ITS MAJOR BATTLEFIELD AUTOMATION PROGRAMS SINCE 13 APRIL 77

BAA IV

1979

FT GORDON, GA

SINCE FORT GORDON ENJOYED THEIR ROLE AS HOST AND DID SUCH A GREAT JOB FOR BAA III, THEY WERE SELECTED TO HOST BAA IV WHICH HAD AS ITS PURPOSE WHAT IS SHOWN HERE.

PAUSE

PURPOSE
BAA IV
PURPOSE

ADDRESS TRAINING, COMMUNICATIONS STRUCTURE, STANDARDIZATION AND RESOURCES TO SUPPORT BAS FOR THE MID 1980'S.

LOGO

BAA V

THEME

THIS BRINGS US UP TO DATE BECAUSE AS I SAID EARLIER, BAA V WAS HELD 29-31 JULY AT FORT HUACHUCA, ARIZONA. OUR PURPOSE WAS AS SHOWN HERE.

PAUSE

PURPOSE   BAA V
PURPOSE

FOCUS ON THE ARCHITECTURAL REQUIREMENTS POSED BY ECS^2 AND THE SOLUTIONS TO MEET THOSE REQUIREMENTS AS VIEWED BY THE COMBAT DEVELOPERS, MATERIEL DEVELOPERS, AND THE RESOURCE MANAGERS.

BAA V
OBJECTIVES

ECS^2

THE HUB OF BATTLEFIELD AUTOMATION

1980 AND BEYOND"

TO DO THAT, WE CHOSE THIS THEME AND THESE OBJECTIVES FOR THE MEETING.

PAUSE

-ESTABLISH WHAT WE WANT.
-WHAT IT IS SUPPOSED TO DO.
-OUTLINE ACTIONS NECESSARY TO FIELD THE OBJECTIVE SYSTEM.
--RESPONSIBILITIES OF PROPONENTS
--PRIORITIES FOR DEVELOPERS
--MILESTONES FOR REQUIRED ACTIONS

BAA V
ISSUE FORMAT

THE ISSUES THAT WERE DISCUSSED ARE SHOWN HERE. AND FOLLOWED THE FORMAT SHOWN.

|	
ISSUE #1 & #2	PRESENTED BY CACDA
ISSUE #3	PRESENTED BY TRADOC/DARCOM
ASSESSMENT	DARCOM

ISSUES
- INFO
- EXECU
  SYSTEM O

THIS MORNING I WOULD LIKE TO GIVE YOU THE MAIN THRUST OF THE PRESENTATION BY CACDA ON ISSUES #1 AND #2.

THE ORIGINAL PRESENTATION GIVEN AT BAA V HAD A SCENARIO BASE TO STRESS COMPARATIVE EFFICIENCIES IN TIME AND COORDINATION BETWEEN CURRENT MANUAL SYSTEMS AND THE PROPOSED AUTOMATED SYSTEMS. HOWEVER, IN THE INTEREST OF TIME, WE WILL OMIT THAT PORTION AND DISCUSS THE INFORMATION REQUIREMENTS AND PRESENT THE ECS² CONCEPT FOR SOLVING THOSE REQUIREMENTS.

INFORMATION
- COLLECTED
- VERIFIED

EXCHANGE INFORMATION
- MANUAL
- TIME CONSUMING
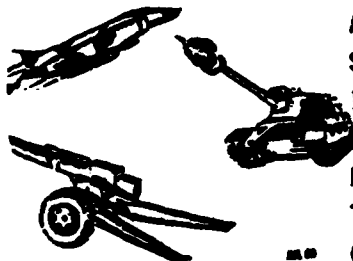
IN OUR SCENARIO, WE PORTRAYED A BRIEF AND PARTIAL LIST OF THE ACTIONS WHICH MUST BE ACCOMPLISHED TO GET A MISSION UNDERWAY AND GIVEN THAT THE ESTIMATE PROCESS IS CONTINUOUS, THERE IS CRITICAL INFORMATION WHICH MUST BE COLLECTED, VERIFIED AND PRESENTED RAPIDLY TO THE COMMANDER IN A USABLE FORMAT IN ORDER FOR HIM TO MAKE PRUDENT OPERATIONAL DECISIONS. EXAMPLES OF THIS INFORMATION WILL BE DISCUSSED IN A MOMENT. ALTHOUGH MOST ACTIONS ARE ACCOMPLISHED CONCURRENTLY, VITAL INPUT TO THE COMMANDER IS AFFECTED BY SIGNIFICANT TIME LAGS INCURRED BY PHYSICAL COORDINATION REQUIREMENTS. THE EMPHASIS HERE IS THAT ATTACKING UNITS CANNOT EXPECT A FRAGO UNTIL MINIMAL DIVISION STAFF INPUTS ARE COMPLETE. WHILE WE ARE BEGINNING TO AUTOMATE INFORMATION COLLECTION, THE ANALYSIS OF THIS INFORMATION AND THE ABILITY TO DISTRIBUTE USABLE, DISCIPLINED DATA THRU COMMAND POSTS IS BASICALLY STILL DONE MANUALLY AND IS TIME CONSUMING. THIS INCLUDES PROCESSING OF INFORMATION AND ORDERS. THE CURRENT SYSTEM WAS DESIGNED TO FUNCTION IN AN ENVIRONMENT FAR LESS DYNAMIC THAN THAT IN CURRENT THREAT PROJECTIONS.

BLANK

RESPONSIVENESS IS AFFECTED BY THE CHARACTERISTICS OF THE HIGHLY
MOBILE BATTLEFIELD AND GREATER DISTANCES BETWEEN FRIENDLY
ELEMENTS. DUE TO LENGTHY VOICE AND RECORD TRAFFIC, TRANSMISSION
SYSTEMS READILY IDENTIFY KEY COMMAND CONTROL NODES. THE
SYSTEM ALSO TENDS TO BECOME OVERLOADED. FLEXIBILITY IS
AFFECTED BECAUSE INFORMATION TENDS TO FLOW AND REMAIN WITHIN
FUNCTIONAL AREAS AND IS NOT READILY AVAILABLE THROUGHOUT THE
COMMAND STRUCTURE. WHAT THE COMMANDER IS FACED WITH, THEN,
IS A DECISION WHETHER TO WAIT FOR ADEQUATE INFORMATION TO BE
PROVIDED AND DELAY HIS DEPARTURE OR TO CROSS THE START POINT
ON TIME WITH INCOMPLETE INFORMATION AND DEPEND UPON ENROUTE
BRIEFING AND PLANNING. IN THE SITUATION WE PORTRAYED, IT WAS
OBVIOUS THAT A MAJOR PENETRATION REQUIRED THAT THE EXECUTION
TIME BE MET. THEREFORE, THE DIV (-) MOVED OUT AS SOON AS IT
WAS PHYSICALLY READY WITH INCOMPLETE INFORMATION OR PLANNING,
AND THE SUCCESS OR FAILURE OF THE MISSION REVERTED LARGELY TO
"SEAT OF THE PANTS" COMMAND CONTROL, MORE PROPERLY TITLED
REACTIVE COMMANDING. OUR OBJECTIVE IS ACTIVE COMMANDING, WHICH
HAS TO BE SUPPORTED BY AN ADEQUATE SYSTEM THAT PROVIDES
INFORMATION NECESSARY TO MAKE DECISIONS WITH REASONABLE RISK.
ALL INFORMATION REQUIRED IS AVAILABLE SOMEWHERE ON THE
BATTLEFIELD. THE KEY IS TO RAPIDLY RETRIEVE CRITICAL
INFORMATION TO ALLOW THE COMMANDER TO REACT MORE QUICKLY
THAN THE ENEMY IN ACTION AND ORDERS.

;WHILE THE COMMANDER DID INITIATE PRELIMINARY ACTIONS, TO   BLANK
INCLUDE PLANNING GUIDANCE, IF HE EXPECTS TO ACHIEVE EFFECTIVE
COMMAND CONTROL, HE MUST DO THE THINGS SHOWN ON THIS SLIDE.

PAUSE

BATTLEFIELD FUNCTIONAL AREAS

WE ALSO KNOW THAT PREVIOUS ANALYSES INDICATE THAT BATTLEFIELD   BLANK
FUNCTIONS ARE GROUPED INTO FIVE MAJOR AREAS OF MANEUVER, AIR
DEFENSE, COMBAT SERVICE SUPPORT, INTEL/EW, AND FIRE SUPPORT
AS SHOWN ON THIS SLIDE.

INFORMATION

BLANK   INFORMATION WHICH IS ALREADY RESIDENT WITHIN THE FUNCTIONAL AREAS
OF THE BATTLEFIELD IS THE KEY TO THE SUCCESSFUL ACCOMPLISHMENT
OF THE COMMANDER'S TASKS.

KEY INFO
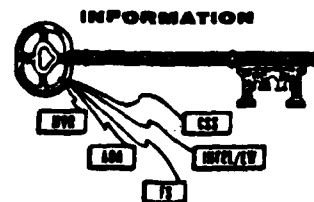
PROGRAMS TO IDENTIFY, COLLATE, AND MAKE AVAILABLE THIS
BLANK   INFORMATION HAVE BEEN WELL UNDERWAY FOR THE PAST FEW YEARS.
EFFORTS SUCH AS THE ARMY BATTLEFIELD INTERFACE CONCEPT, THE
TECHNICAL INTERFACE CONCEPT, AND THE CORPS INFORMATION FLOW,
JUST TO NAME A FEW, ARE BEGINNING TO YIELD TANGIBLE RESULTS.
IT IS APPARENT THAT IF WE HOPE TO GIVE THE COMMANDER AN
INTEGRATED DEPICTION OF THE BATTLEFIELD, A DISCIPLINED
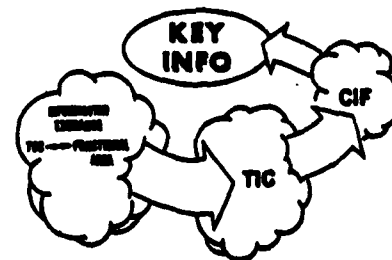
DUAL THRUST
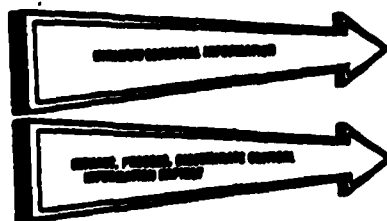
CAPABILITY MUST EXIST FOR EXCHANGING INFORMATION. ESSENTIALLY,   BLANK
THEN, THE THRUST OF THIS BRIEFING IS TWO-FOLD. FIRST, TO SHOW
WHAT WE HAVE IDENTIFIED THE MINIMUM ESSENTIAL INFORMATION THAT
COMMANDERS REQUIRE FOR DECISION MAKING, AND SECOND, TO DESCRIBE
A MEANS TO EXTRACT, PROCESS, AND DISSEMINATE THIS CRITICAL
BLANK   INFORMATION RAPIDLY.   BLANK

FRIENDLY ACTIVITY (ACTIONS, TIME, UNIT, LOC)
CMD MISSION
EN ACTIVITY (LOC, TIME, TYPE)
BATTLE LOSSES
TASK ORGANIZATION
AVAILABLE SUPPLY RATE (RDS BY TYPE)

MATRIX

MANEUVER	FS	ADA	INTEL/EW	CSS	CMD
⊗	⊗	⊗	⊗	⊗	X
⊗	X	X	X	X	⊗
⊗	⊗	⊗	⊗	⊗	X
⊗	⊗	⊗	⊗	⊗	X
⊗	X	X	X	X	⊗
X	X	X		⊗	

THESE SLIDES DEPICT EXAMPLES OF THE INFORMATION ELEMENTS
REQUIRED BY THE COMMANDER AND STAFF IN OUR SCENARIO TO
ACCOMPLISH THEIR TASKS. LISTED ON THE LEFT ARE THE EXAMPLES
OF A FEW OF THE ELEMENTS OF INFORMATION. THE X'S TO THE RIGHT
DENOTE THE FUNCTIONAL AREA(S) WHICH HAVE A REQUIREMENT FOR
THIS INFORMATION.

THE CIRCLED X'S IN THE MATRIX DENOTE WHICH FUNCTIONAL AREAS
GENERATE THE INFORMATION, THEREBY DESCRIBING THE REQUIREMENT
FOR EXCHANGE OF THE CRITICAL INFORMATION BETWEEN THE FUNCTIONAL
AREAS.

IT MUST BE NOTED THAT THE LIST IS NOT STATIC, BUT IS A DYNAMIC
DOCUMENT SUBJECT TO CHANGE IN DOCTRINE. REFINEMENT OF THIS LIST
WILL BE ACCOMPLISHED PRIMARILY IN CONJUNCTION WITH FIELD USERS
IN AN EVOLUTIONARY MANNER. WHILE THE KEY ELEMENTS OF
INFORMATION PROVIDE THE BREAKDOWN OF INFORMATION REQUIRED, THE
TIMELINESS REQUIREMENT MUST ALSO BE ADDRESSED. THUS, IT WAS
NECESSARY TO QUANTIFY THE ABILITY OF THE BATTLEFIELD FUNCTIONAL
AREAS TO PROCESS AND DISTRIBUTE DATA.

A SCENARIO BASED STUDY, THE ARMY COMMAND AND CONTROL MASTER
PLAN, SUPPORTS THE REQUIREMENT FOR MORE TIMELY PROCESSING OF
INFORMATION. AS AN EXAMPLE, AC^{2}MP STATES THAT, IN THE MOST
STRESSED CASE, DIVISION HAS A REQUIREMENT TO COMPLETE THE CDR
ESTIMATE AND ISSUE A FRAGMENTARY ORDER MOVING A BRIGADE TO
COUNTER A THREAT PENETRATION AS SHOWN HERE. THE STUDY ASSESS-
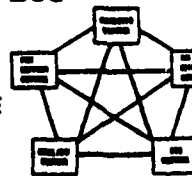MENT OF THE PRIMARILY MANUAL BASELINE SHOWED THIS TIME TO

ACTION	REQUIREMENT	BASELINE
CDR ASSESSMENT	3 HOURS	

BLANK

PERFORMANCE COMPARISON

ACTION	REQUIREMENT	BASELINE
CDR ESTIMATE	3 HOURS	8-12 HOURS

61

ACTION	REQUIREMENT	BASELINE
CDR ESTIMATE	3 HOURS	6-12 HOURS
G-2 ESTIMATE	1 HOUR	

ECS²

XECUTIVE
:ONTROL
;UBORDINATE
;YSTEMS

BLANK ACCOMPLISH THIS PROCESS. AS ANOTHER EXAMPLE, AC²MP DEMONSTRATES
BLANK THIS REQUIREMENT FOR COMPLETING A G-2 ESTIMATE. PERFORMANCE OF
THE BASELINE IS AS INDICATED. CLEARLY, A SUBSTANTIAL GAP EXISTS
BETWEEN THE COLLECTION AND DISSEMINATION OF CRITICAL, PROCESSED
INFORMATION. BASED ON THIS LACK OF RESPONSIVENESS, OUR
IMMEDIATE NEED CENTERS AROUND SOLIDIFYING OUR EFFORTS TO INSURE
THAT THESE TIME REQUIREMENTS ARE MET. SO, WE HAVE IDENTIFIED   BLANK
A CONCEPT FOR EVOLVING AN INTEGRATED ARCHITECTURE TO SATISFY
THESE NEEDS IN ECS².

ACTION	REQUIREMENT	BASELINE
CDR ESTIMATE	3 HOURS	6-12 HOURS
G-2 ESTIMATE	1 HOUR	6 HOURS

THE LOGO ON THIS TITLE SLIDE IS MORE THAN JUST A LOGO. IT IS
A GRAPHICAL REPRESENTATION OF THE PRODUCT ORIENTED CONCEPT THAT
IS THE BASIS OF THIS APPRAISAL.

IN ORDER TO PRESENT A BRIEF BACKGROUND ON ECS², IT IS NECESSARY
TO HAVE A COMMON UNDERSTANDING OF THE BASIC PRECEPTS JUST
DISCUSSED. FIRST, DURING THE CONDUCT OF THE NEXT WAR, IT IS A
FACT THAT WE WILL BE BOTH OUT-GUNNED AND OUT-NUMBERED. THE
REMAINING PARAMETER IS OUR ONLY SHOT AT INFLUENCING THE OUTCOME
BLANK OF THE BATTLE. WHILE THIS QUESTION OF "HOW WE OUTSMART THE ENEMY"
MAY APPEAR TO BE A COMPLEX PROBLEM, IT ACTUALLY BOILS DOWN TO AN
BLANK ACCURATE, TIMELY INFORMATION ARRIVING AT THE RIGHT PLACE AND ITS
EFFECTIVE USE. INFORMATION THEN BECOMES A FORCE MULTIPLIER.

INFORMATION

EFFECTIVE DECISIONS
ARE BASED ON

THIS SLIDE PORTRAYS THE PRINCIPAL CHARACTERISTICS OF INFORMATION
AS IT APPLIES TO DECISION MAKING. OF THE THREE CHARACTERISTICS
SHOWN, ONE IS CONSIDERABLY MORE IMPORTANT THAN THE OTHER TWO.
BASED ON SEVERAL INFORMATION CHARACTERISTIC STUDIES, PARTICULARLY

WHERE INTERVIEWS WERE CONDUCTED WITH FIELD COMMANDERS, GETTING
INFORMATION ON TIME WAS THE MOST IMPORTANT FACTOR. INFORMATION
NOT DELIVERED BEFORE IT PERISHES HAS NO VALUE. WE ARE NOT
SAYING THAT ERRONEOUS INFORMATION GIVEN IN A TIMELY MANNER IS
ACCEPTABLE. QUITE THE CONTRARY, WHILE THE APPLICATION OF
AUTOMATION IS AN ANSWER TO THE TIMELINESS PROBLEM, IT ALSO HAS
THE CAPABILITY OF INCREASING ACCURACY AND RESOLUTION AND ASSISTING
THE COMMANDER IN THE EFFECTIVE USE OF THIS INFORMATION BY MEANS
OF DISPLAYS AND CORRELATION CAPABILITIES.

DECISION PROCESS

LET'S LOOK FOR A MOMENT AT THE COMMANDER'S DECISION PROCESS. BLANK
EVENTS FOR THIS MODEL ARE TRIGGERED FROM THE SOURCES SHOWN ON
THIS SLIDE.
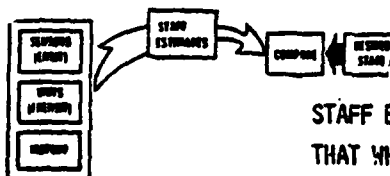
DECISION PROCESS

THIS, IN TURN, IS FED TO THE COMMANDER, THRU BLANK
STAFF ESTIMATES IN THE PLANNING STAGE, SO THAT HE CAN COMPARE IT WITH
THAT WHICH HE CONSIDERS TO BE THE DESIRED STATE.
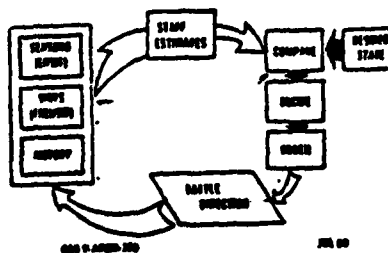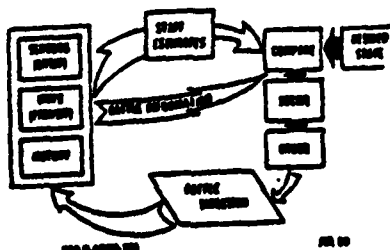
HE THEN MAKES HIS BLANK
DECISION AND ISSUES HIS ORDERS WHICH START THE CYCLE OVER AGAIN.
BUT THIS PROCESS TAKES ON ANOTHER DIMENSION DURING THE ACTUAL

DECISION PROCESS

CONDUCT OF THE BATTLE. WHILE IT MUST BE UNDERSTOOD AND PRACTICED
THAT ESTIMATES ARE A CONTINUING PROCESS, THE COMMANDER MUST GET
HIS BATTLE INFORMATION DIRECTLY. THE APPLICATION OF AUTOMATION BLANK
IS NOT TO PROVIDE MORE INFORMATION TO THE COMMANDER, BUT TO
PROVIDE THE KEY INFORMATION MORE TIMELY AND ACCURATELY SO THAT HE
CAN COMPLETE HIS DECISION PROCESS MORE RAPIDLY THAN THE ENEMY
COMMANDER. IT IS THE ABILITY TO EFFECTIVELY APPLY THIS PROCESS
THAT PERMITS MAINTAINING THE INITIATIVE AND WINNING THE BATTLE.

DECISION PROCESS

REFERRING ONCE AGAIN TO THE CLOSED LOOP SYSTEM ON THIS SLIDE, BLANK
AUTOMATED SYSTEMS HAVE BEEN OR ARE BEING DEVELOPED TO COLLECT
INFORMATION REPRESENTED IN THE BOXES ON THE LEFT. SOME PROGRAMS

ARE ALSO UNDERWAY TO DEVELOP AUTOMATED STORING AND PROCESSING
OF THIS TECHNICAL DATA GENERATED BY THESE COLLECTORS. HOWEVER,
WE HAVE GAPS IN SOME AREAS WHERE NO AUTOMATION PROGRAMS ARE
UNDERWAY FOR THESE PROCESSES. WE ALSO LACK PROGRAMS FOR
DEVELOPING AUTOMATION TO PRESENT KEY DECISION-MAKING INFORMATION
TO THE COMMANDER AND TO PROVIDE FOR DISSEMINATION OF GUIDANCE.
THESE GAPS MUST BE FILLED IN ORDER TO ACHIEVE A BALANCED AND
INTEGRATED COMMAND/CONTROL SYSTEM.

INFORMATION
IS PROCESSED AT OPFACS

BLANK   EACH FUNCTIONAL AREA IS REPRESENTED BY A COMBINATION OF RESOURCES
THAT FORM OPERATIONAL FACILITIES IN THE JOINT MEDIA COMMONLY CALLED
OPFACS.

IT IS WITHIN THESE OPFACS THAT INFORMATION IS PROCESSED. THE
IMPORTANCE OF THIS FACT IS THAT IT PROVIDES IDENTIFIABLE NODES
ON THE BATTLEFIELD THROUGH WHICH INFORMATION MUST FLOW. INFORMATION
SUPPORTS THE DECISION-MAKING PROCESS, BUT THE OPFACS ARE THE
FACILITIES THROUGH WHICH THAT INFORMATION IS EFFECTIVELY COLLECTED,
PROCESSED, AND DISSEMINATED. THE FIVE OPFACS SHOWN ON THIS SLIDE
ALSO COINCIDE WITH THE FIVE MAJOR FUNCTIONAL AREAS OF THE
BATTLEFIELD.

**TECHNICAL
INFORMATION PRODUCTS**

• BATTALION CENTER OF MASS
(1-94 MECH LOC AT YZ123673)

INFORMATION PRODUCTS

• **TECHNICAL**

• **STAFF**

• **COMMAND RELATED**

THREE DISTINCT TYPES OF INFORMATION PROCESSED IN THESE OPFACS
ARE IMPORTANT TO RECOGNIZE - TECHNICAL, STAFF, AND COMMAND
RELATED. THE PREPONDERANCE OF AUTOMATION EFFORTS TO DATE HAVE
BEEN DIRECTED AT THE MANIPULATION OF TECHNICAL DATA - EXAMPLES
OF WHICH ARE SHOWN ON THE SLIDES ON THE RIGHT. TECHNICAL DATA IS
THE VERY ESSENCE FROM WHICH DECISION MAKING INFORMATION IS DERIVED.

• PERCENT BASIC LOAD ON HAND
(105 MM MAIN GUN—78%)

• EMITTER LOCATION
(SA4 LOC AT YZ128994)

**STAFF INFORMATION
PRODUCTS**

INFORMATION PRODUCTS

• **TECHNICAL**

• **STAFF**

• **COMMAND RELATED**

• FRIENDLY UNIT LOC
(FRONT LINE TRACE)

• MAJOR END ITEM
REPAIR STATUS

• ENEMY 2D ECHELON
DISPOSITION

64

INFORMATION PRODUCTS

- **TECHNICAL**
- **STAFF**
- **COMMAND RELATED**

IT IS FIRST REFINED INTO STAFF INFORMATION, EXAMPLES OF WHICH ARE SHOWN ON THIS SLIDE, WHICH ALLOWS THE STAFF TO DEVELOP ALTERNATIVE COURSES OF ACTIONS FOR THE COMMANDER'S CONSIDERATION. TECHNICAL DATA CONTINUOUSLY FEEDS THE STAFF ESTIMATES. FINALLY, THE COMMAND RELATED PRODUCTS EVOLVE, EXAMPLES AS SHOWN HERE. THESE FINISHED PRODUCTS PROVIDE TACTICAL DIRECTION AND SUPPORT ACTIVE COMMANDING. IT IS IMPERATIVE THAT OUR MANAGEMENT OF STAFF AND COMMAND RELATED PRODUCTS RECEIVE GREATER EMPHASIS.

UPDATED SITUATION MAP
OPERATIONAL READINESS STATUS MAJOR WPNS SYSTEMS
ENEMY CAPABILITY TO REINFORCE PENETRATION

INTERCONNECTIVITY
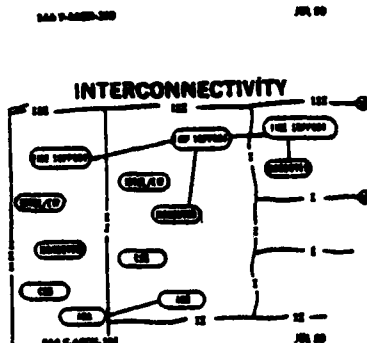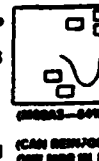
THIS IS A REPRESENTATIVE GRAPHIC DEPICTING INTERCONNECTIVITY AS IT IS EMPLOYED TODAY. MOST INTERCONNECTIVITY EFFORT IN AUTOMATION TO DATE HAS BEEN DEVOTED TO MEETING TECHNICAL PROCESSING REQUIREMENTS IN A STOVE-PIPE MANNER BETWEEN LIKE FUNCTIONS SUCH AS FIRE SUPPORT OR ADA TO ADA.
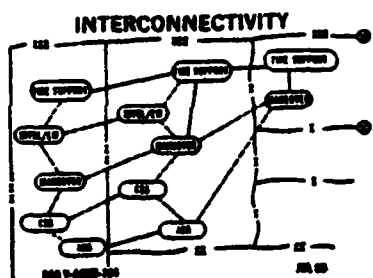
CURRENTLY, THERE IS A LINK BETWEEN MANEUVER AND FIRE SUPPORT BY THE VARIABLE FORMAT MESSAGE ENTRY DEVICE OF TACFIRE LOCATED IN THE FIRE SUPPORT ELEMENT IN THE TOC. IT SHOULD BE POINTED OUT, HOWEVER, THAT NEARLY ALL THE REMAINING INTERCONNECTIVITY IS

INTERCONNECTIVITY

STILL MANUAL, WHICH MAY SOUND STRANGE CONSIDERING THE EFFORT THAT HAS BEEN PUT INTO AUTOMATION THUS FAR. OUR CONCEPTUAL WORK, SUCH AS THE ABIC, HAS ADDRESSED THE NEED FOR INTERCONNECTIVITY BUT NOWHERE HAS A UNIFORM APPROACH BEEN TAKEN TO ADDRESS THE INTERCONNECTIVITY REQUIREMENTS REPRESENTED BY THE DASHED LINES BETWEEN THE FIVE MAJOR FUNCTIONAL AREAS TO FORM AN INTEGRATED COMMAND CONTROL CAPABILITY. THIS INTERCONNECTIVITY IS ESSENTIAL TO CLOSE THE LOOP ON THE DECISION PROCESS.

PROBLEM

THIS, THEN, SHOWN ON THE LEFT IS THE PROBLEM.

ECS^2

ECS^2 IS OUR APPROACH TO SOLVING THIS PROBLEM. IT PROVIDES THE EVOLUTIONARY, COMMON-SENSE APPLICATION OF AUTOMATION AND COMMUNICATIONS TO THE BATTLEFIELD DECISION-MAKING PROCESS.
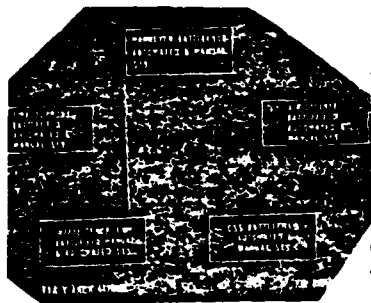
THE SLIDE ON THE RIGHT PROVIDES A GRAPHIC PORTRAYAL OF THE ORIGINALLY ENVISIONED ECS^2 CONCEPT. IT SHOWS REPRESENTATIVE SUBORDINATE SYSTEMS CLUSTERED AROUND PARENT CONTROL SYSTEMS. THE POINT TO BE MADE ON THIS SLIDE, HOWEVER, IS THAT PREVIOUS ANALYSES OF BATTLEFIELD AUTOMATION EFFORTS CLEARLY INDICATE THAT BASIC FUNCTIONS AND TASKS FALL INTO FIVE MAJOR AREAS AS WE HAVE POINTED OUT BEFORE. IN TURN, THERE IS A REQUIREMENT FOR EXCHANGE OF COMMANDER AND STAFF INFORMATION AMONG THESE FIVE DISTINCT SYSTEMS. IT SHOULD ALSO BE POINTED OUT THAT EACH OF THE FUNCTIONAL AREAS HAS A COMMANDER AND A COMMAND CONTROL SYSTEM IN ITS OWN RIGHT. RECENT ANALYSIS OF THIS CONCEPT HAS REMOVED THE EXECUTIVE C^2 SYSTEM FROM THE CENTER, AND ESTABLISHED A FIFTH CONTROL SYSTEM FOR MANEUVER AS SHOWN ON THE LEFT. THIS REMOVES THE IMPLICATION THAT ALL INFORMATION MUST FLOW THROUGH THE TACTICAL OPERATIONS CENTER BEFORE GETTING TO ANOTHER FUNCTIONAL AREA. THE TERMS ADMIN/LOG, INTEL, AND FIELD ARTILLERY HAVE BEEN CHANGED TO CSS, INTEL/EW, AND FIRE SUPPORT.
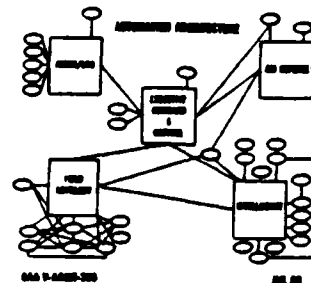
BLANK   NOW I'M GOING TO BUILD A GRAPHIC FOR YOU THAT FUNCTIONALLY DESCRIBES THE ECS^2 CONCEPT. THIS FORMAT WAS ADOPTED BECAUSE IT SERVES AS A COMMON FRAMEWORK FOR DESCRIBING USER REQUIREMENTS FOR A HOST OF PROGRAMS AND IS READILY ADAPTABLE TO ANALYTICAL MODELING OF THE FUNCTIONAL AREAS AND THEIR INTERRELATIONSHIPS.

EACH BLOCK REPRESENTS A BATTLEFIELD FUNCTION BUT NOT NECESSARILY
A COMPUTER. THE FORCE CONTROL BLOCK REPRESENTS THE COMMANDER,
AND THE SOLID HORIZONTAL LINE REPRESENTS MINIMUM ESSENTIAL OR
KEY INFORMATION EXCHANGE BETWEEN THE COMMANDER OF THE FORCE AND

BLANK HIS FUNCTIONALLY ASSIGNED SUBORDINATES. THE DASHED HORIZONTAL
LINE DEPICTS THE REQUIREMENT FOR INFORMATION TO BE EXCHANGED
AMONG FUNCTIONAL AREAS.

BLANK IN LIKE MANNER, THIS INFORMATION EXCHANGE REQUIREMENT EXISTS
AT BATTALION, BRIGADE, DIVISION AND THEATER. THE DASHED

BLANK RECTANGLE DEPICTS THE STOVEPIPE EFFECT WITHIN EACH FUNCTIONAL
AREA WHERE INFORMATION FLOWS VERTICALLY. ONCE AGAIN, IT IS
HERE WITHIN FUNCTIONAL AREAS THAT THE PREPONDERANCE OF OUR
AUTOMATION EFFORTS HAVE BEEN DIRECTED. AUTOMATION OF ESSENTIAL
INFORMATION ON THE HORIZONTAL LINES, THAT IS, AMONG FUNCTIONAL
AREAS, HAS NOT KEPT PACE. WITH THIS FUNCTIONAL OUTLINE IN MIND,
LET'S NOW DISCUSS EACH OF THE THREE COMPONENTS OF ECS2.

SUBORDINATE SYSTEM

- BELONGS TO THE FUNCTIONAL AREA
- CRUNCHES TECHNICAL DATA:

  EXAMPLES: TPQ-37 (FIREFINDER)
  SMLS
  TSQ114 (TRAILBLAZER)
  BATTERY COMPUTER SYSTEM

- NOT DESIGNED TO PROVIDE INTEGRATED AND
  PROCESSED DATA TO THE COMMANDER
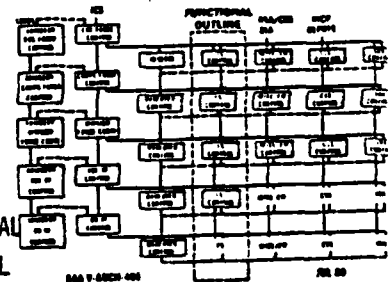
BLANK WORKING FROM THE BOTTOM UP, WE'LL BEGIN WITH THE SUBORDINATE
SYSTEMS. THE SUBORDINATE SYSTEMS ARE AUTOMATED OR MANUAL
SYSTEMS DESIGNED TO DO WORK IN FUNCTIONAL AREAS. EXAMPLES OF
THESE ARE SHOWN ON THE SLIDE. THEY DEAL LARGELY IN TECHNICAL
DATA. THEY CONTAIN LITTLE, IF ANY, DATA THAT CAN BE FED
DIRECTLY TO THE COMMANDER IN A USEFUL FORMAT. WHAT USEFUL DATA
THEY DO CONTAIN IS NOT NORMALLY DIRECTLY ACCESSIBLE. THIS IS
NOT TO DOWNPLAY THE IMPORTANCE OF SUBORDINATE SYSTEMS. CONVERSELY,
THEY ARE ACCOMPLISHING IMPORTANT JOBS ON THE BATTLEFIELD. WHAT
IT DOES POINT OUT, HOWEVER, IS THE DIFFERENCE BETWEEN THE

COLLECTION AND PROCESSING OF RAW DATA AND THE AVAILABILITY OF
USEFUL INFORMATION FOR COMMAND CONTROL PURPOSES.

TO FILL THAT ROLE, THE CONTROL SYSTEM PERFORMS A THREEFOLD
MISSION. FIRST, IT PROVIDES THE FUNCTIONAL AREA COMMANDER WITH
THE CAPABILITY TO PROCESS AND ANALYZE SELECTED DATA FOR HIS
OWN COMMAND CONTROL PURPOSES. SECOND, IT IS AN ELEMENT OF THE
COMMAND CONTROL NETWORK SHARING SELECTED INFORMATION WITH THE
OTHER CONTROL SYSTEMS. THIRD, IT PRODUCES KEY INFORMATION TO
SUPPORT THE FORCE COMMANDER'S DECISION PROCESS. PREVIOUSLY
IDENTIFIED CONTROL SYSTEMS SUCH AS TSQ-73, AS AN EXAMPLE,
DEALS WITH THE REAL-TIME AIR BATTLE IN TERMS OF TARGET QUEUING
AND TARGET SERVICING. THERE IS LITTLE PROCESSED INFORMATION
CURRENTLY AVAILABLE FROM THIS SYSTEM THAT WOULD AID AIR DEFENSE
OR FORCE LEVEL COMMAND DECISION PROCESSES AS PREVIOUSLY DESCRIBED.
IN ORDER TO FULFILL THE ECS^2 DEFINITION OF A CONTROL SYSTEM, IT
MUST BE CAPABLE OF HANDLING STAFF AND COMMAND RELATED INFORMATION
AND BE INTERACTIVE WITH OTHER CONTROL SYSTEMS.
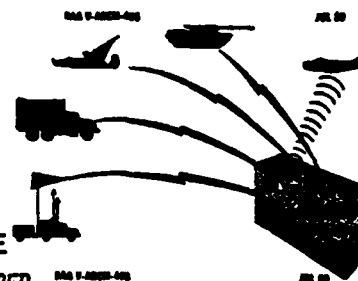
THUS, THE TASK OF INTEGRATING CONTROL SYSTEM INFORMATION
PROCESSING AT THE FUNCTIONAL NODES MUST BE EXAMINED INDIVIDUALLY
AT EACH NODE OR SYSTEM, AND POTENTIAL MODIFICATION DETERMINED
INDIVIDUALLY BASED ON THE DESIGN AND REQUIREMENTS EXISTING THERE.
AN EVOLUTIONARY FIELDING APPROACH WOULD SUGGEST A FIRST PHASE
IMPLEMENTATION WITHOUT MODIFICATION TO EXISTING CONTROL SYSTEMS.

AS THE SLIDES INDICATE, THE EXECUTIVE OR FORCE CONTROL SYSTEM IS THE ONE THAT TIES TOGETHER THE FIVE MAJOR FUNCTIONS OF THE BATTLEFIELD AND ALSO PROVIDES THE COMMANDER WITH CRITICAL DECISION-MAKING INFORMATION. THE SOFTWARE, COMMUNICATIONS, AND DISTRIBUTED CAPABILITIES ARE THE KEY POINTS OF THIS COMPONENT. THE EXECUTIVE SYSTEM IS CLOSELY ASSOCIATED WITH THE CONTROL SYSTEMS AT EACH FUNCTIONAL AREA; HOWEVER, WHETHER OR NOT SEPARATE HARDWARE IS REQUIRED HAS NOT BEEN DETERMINED AT THIS POINT. IN ITS OBJECTIVE CONFIGURATION, THIS COMPONENT WILL SATISFY THE REQUIREMENTS STATED IN THE ARMY COMMAND AND CONTROL MASTER PLAN WHICH CALLS FOR DISTRIBUTED DATA AND DISTRIBUTED PROCESSING. THESE SPECIFIC DEFINITIONS ARE SHOWN HERE.
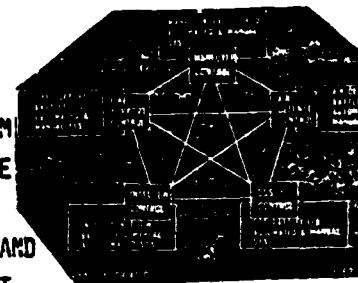
DISTRIBUTED DATA

DISTRIBUTED PROCESSING

THESE IN TURN SUPPORT THE ESSENTIAL OPERATIONAL DESIGN CRITERIA OF CONTINUITY OF OPERATIONS, SURVIVABILITY, SECURITY, INTEROP, RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND STANDARDIZATION. SURVIVABILITY IN PARTICULAR NEEDS TO ADDRESS THE INTEGRATED BATTLEFIELD AND ITS NUCLEAR EMP IMPLICATIONS.

NOW WHAT I'M GOING TO DO IS REEMPHASIZE KEY POINTS IN THE CONCEPT. THERE IS MORE THAN ONE COMMAND CONTROL SYSTEM ON THE BATTLEFIELD.
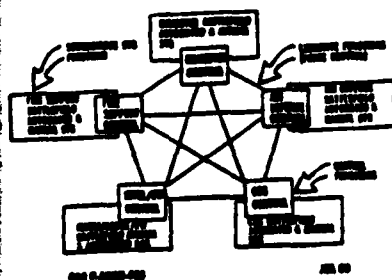
SUBORDINATE SYSTEMS FEED INFORMATION TO THE CONTROL SYSTEM TO SATISFY THE FUNCTIONAL AREA COMMANDER'S REQUIREMENTS. ONLY A SMALL PORTION OF THIS INFORMATION IS RELEASED TO THE INTEGRATED NETWORK WHICH THEN BECOMES AVAILABLE TO THE FORCE CONTROL AND OTHER FUNCTIONAL AREAS.

BLANK

69
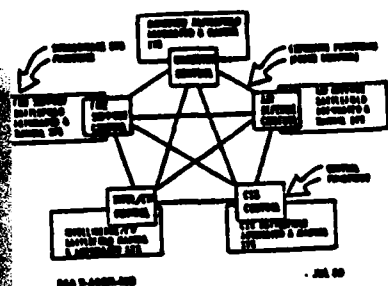
THE FUNCTIONAL AREA COMMANDER USES HIS CONTROL SYSTEM TO
ACCOMPLISH HIS OWN COMMAND CONTROL FUNCTIONS UNDER A DIFFERENT
SET OF INFORMATION REQUIREMENTS.

THE EXECUTIVE SYSTEM TIES TOGETHER THE NETWORK OF FIVE CONTROL
SYSTEMS THAT REPRESENT THE FORCE COMMANDER'S C^2 SYSTEM.
ONLY KEY INFORMATION IS CONTAINED IN THIS INTEGRATED NETWORK
WHICH THE FORCE COMMANDER AND FUNCTIONAL AREA COMMANDERS MAY
DRAW FROM. THE COMMANDER OF THE FORCE OPERATES PRIMARILY FROM
THE MANEUVER CONTROL SYSTEM AND THE EXECUTIVE SYSTEM IS HIS
PRIMARY MEANS OF RECEIVING HIS BATTLE INFORMATION.

TO PROVIDE FOR THIS MULTIPLE STORAGE AND PROCESSING CAPABILITY,
WE NEED A RESPONSIVE HIGH VOLUME, FLEXIBLE SURVIVABLE COMMUNICATIONS
SYSTEM CAPABLE OF MOVING INFORMATION AMONG THE EXECUTIVE, CONTROL
AND SUBORDINATE SYSTEMS OF ECS^2.

ESSENTIALLY, WE HAVE TO ATTACH THE PROBLEM OF ESTABLISHING THE
EXECUTIVE AND CONTROL SYSTEMS. WE HAVE SUFFICIENTLY STUDIED
THE PROBLEM TO UNDERSTAND THAT ANY FURTHER CONCEPTUAL WORK IS
REPLOWING OLD GROUND. WE KNOW WHAT WE WANT THE CONTROL SYSTEMS
TO DO AND WE HAVE ADEQUATE DOCUMENTATION TO KNOW WHAT INFORMATION
SHOULD BE PASSED. THE NEXT STEP IS TO GET SOMETHING INTO THE
FIELD SO THAT WE CAN BUILD ON EXISTING KNOWLEDGE AND LOGICALLY
EVOLVE AN OBJECTIVE AUTOMATION ARCHITECTURE.

BLANK   THIS EXAMPLE CONTROL SYSTEM POINTS OUT ITS BASIC COMPONENTS.
THE EXECUTIVE COMPONENT PROVIDES DATA TO THE COMMANDER AND THE

OTHER CONTROL SYSTEMS. THE FUNCTIONAL COMMAND CONTROL PORTION
IS THE PART THAT DOES THE FUNCTIONAL AREA COMMANDER'S PROCESSING
OF HIS OWN COMMAND CONTROL, INFORMATION, AND THE COMM REPRESENTS
THE DISTRIBUTED CAPABILITIES.

LET'S CONSIDER THE APPROACH FOR IMPLEMENTING THE CONTROL SYSTEM
NETWORK THAT WE JUST DISCUSSED. TACTICAL COMPUTER SYSTEMS AND
TERMINALS, SUBSETS OF THE FORMER TOS PROGRAM, ARE BEING PLACED
IN COMBAT UNITS IN EUROPE OVER THE NEXT YEAR. THESE SYSTEMS
WILL INITIALLY HANDLE A FEW BASIC FUNCTIONS THAT WILL GIVE THE
TROOPS SOMETHING TO WORK WITH. THIS EARLY EMPLOYMENT WILL
PROVIDE VALUABLE FEEDBACK FOR THE PROTOTYPE MANEUVER CONTROL
SYSTEM WHICH DESIRABLY WOULD BE FIELDED IN 1985. THE VALUE OF
THIS ACTION IS IDENTIFIED WITH THE USER-INTERFACE APPLICATION,
REFINEMENT OF INFORMATION BEING PROCESSED AND DISSEMINATED, AND
THE PRACTICAL APPROACH TO SOLVING COMMUNICATIONS PROBLEMS. IT
IS IN THIS SAME MANNER THAT THE OTHER FOUR CONTROL SYSTEMS
SHOULD EVOLVE.

IN ORDER TO ACHIEVE AN INTEROPERABLE NETWORK IN THE FIELD IN
THE 1985 TIMEFRAME, INITIAL SYSTEMS MUST BE PLACED IN TEST-BED
UNITS AS EARLY AS 1982, USING STANDARDIZED, SHELF ITEMS,
POSSIBLY THE SAME TCS/TCT SYSTEMS AS ARE BEING USED IN EUROPE.

THROUGH AN EVOLUTIONARY PROCESS, PROTOTYPE SYSTEMS SHOULD BE
DEVELOPED AND FIELDED AROUND 1985 COMMENSURATE WITH THE MANEUVER
CONTROL PROGRAM. BETWEEN 1982 AND 1985, WE WOULD EXPECT NO
AUTOMATED LINKS BETWEEN THE EXECUTIVE PROCESSING NETWORK AND THE

EARLY EMPLOYMENT

FEEDBACK:
- USER-INTERFACE APPLICATION
- INFORMATION REFINEMENT
- COMMUNICATIONS SOLUTIONS

71
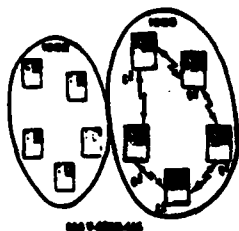
EXISTING CONTROL SYSTEMS. IN THIS SAME TIMEFRAME, THE REQUIREMENTS OF THE CONTROL SYSTEMS FOR FUNCTIONAL AREA COMMAND CONTROL WILL BE DEVELOPED AND REFINED.

PROTOTYPE SYSTEMS FIELDED IN 1985 SHOULD HAVE SOME DISTRIBUTED PROCESSING CAPABILITY AND LIMITED SOFTWARE TO SERVICE THE FUNCTIONAL AREAS.

PAUSE

OBJECTIVE SYSTEMS IN 1989 WILL INCORPORATE ALL OPERATIONAL DESIGN CRITERIA TO INCLUDE STANDARD HARDWARE, LANGUAGE, FORMATS AND PROTOCOL AND WILL BE A TOTALLY INTERACTIVE ARCHITECTURE.
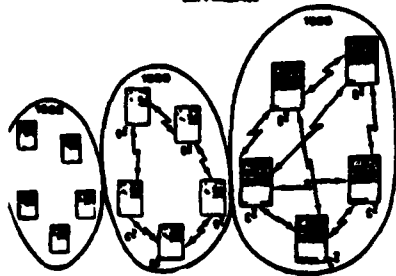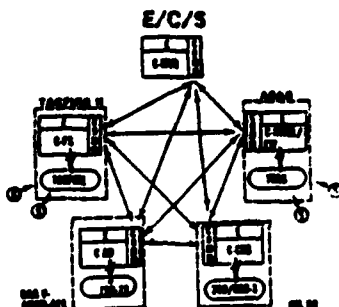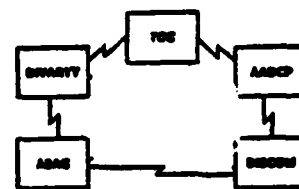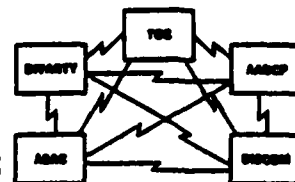
LET ME FOCUS YOUR ATTENTION ON THIS SLIDE TO THESE IMPORTANT POINTS. IN THE LONG RUN, IT MAY BE THAT SYSTEMS SUCH AS TACFIRE AND TSQ-73 WILL EVOLVE INTO TOTALLY INTEROPERABLE CONTROL SYSTEMS, AS INDICATED BY THE DASHED BOXES, BUT WE WILL NOT UNDERSTAND HOW THAT IS ACCOMPLISHED WITHOUT AN EVOLUTIONARY FIELDING. CONTROL SYSTEMS, AS DEFINED IN THIS CONCEPT, MUST BE DEVELOPED UNDER CONFIGURATION MANAGEMENT ON BOTH SIDES OF THE DEVELOPMENT COMMUNITY. AS WE BECOME SMARTER IN THE PRACTICAL APPLICATION, THE FEASIBILITY OF ALTERING EXISTING PROGRAMS TO ASSUME THE ROLE OF CONTROL SYSTEMS MAY INCREASE. IT IS ESSENTIAL THAT WE GET SOMETHING IN THE HANDS OF THE TROOPS NOW IF WE EXPECT TO ARRIVE AT A COHERENT NETWORK BY 1989.

GIVEN THAT WE ACHIEVE ECS^2, IT SHOULD HAVE A VITAL IMPACT ON
OUR COMBAT CAPABILITY.

ECS^2

EXECUTIVE
CONTROL
SUBORDINATE
SYSTEMS
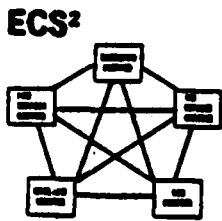
WITH THIS PRESENTATION, WE HAVE DEMONSTRATED THAT WE HAVE MADE
TANGIBLE PROGRESS DESIGNED TO INTEGRATE INFORMATION AND AUTOMATION
ON THE BATTLEFIELD. WE HAVE SPANNED THE GAP OF IDENTIFYING KEY
INFORMATION AND WE HAVE A REALISTIC, ACHIEVABLE CONCEPT FOR
GETTING TO AN INTEGRATED COMMAND CONTROL NETWORK.

ECS^2

EXECUTIVE
CONTROL
SUBORDINATE
SYSTEMS
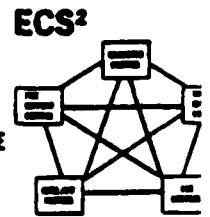
ACTIONS NECESSARY FOR AN EVOLUTIONARY APPROACH
TO FIELD THE OBJECTIVE ECS2:
- NEAR TERM
- FAR TERM

FOLLOWING THE PRESENTATION I HAVE JUST PRESENTED.
ISSUE #3 WAS PRESENTED BY EACH OF THE PROPONENTS FOR THE CONTROL
SYSTEMS AS SHOWN HERE.

PAUSE

TSM ADDRESSED THE REQUIREMENTS TO SUPPORT THE ECS^2 CONCEPT
FOLLOWED BY THE PM PRESENTING ACTIONS NECESSARY TO FIELD A
SYSTEM/SYSTEMS TO SUPPORT THOSE REQUIREMENTS.

FOLLOWING THE CONTROL SYSTEM PRESENTATIONS, TWO PRESENTATIONS ON
COMMUNICATIONS WERE PRESENTED. THE FIRST WAS BY BG LANG, DCDR,
CERCOM, WHICH HIGHLIGHTED THE INADEQUACY OF THE ARMY FUNDING
STRATEGY TO EFFECTIVELY SUPPORT CE HARDWARE AND RAISED THESE
ISSUES.

BAA V
CE ISSUES

E HARDWARE SHORTFALLS
UNDING EMPHASIS ON NEW SYSTEMS
GING OF CE EQUIPMENT
D OF CE REQUIREMENTS

BLANK

PAUSE

MG HILSMAN, CDR, SIG CEN, THEN OUTLINED COMMUNICATIONS SUPPORT
FOR ECS^2 WITH PRIMARY THRUST ON THE PLRS-JTIDS HYBRID.

THE DARCOM ASSESSMENT OF AN APPROACH TO IMPLEMENT THE ECS^2
ARCHITECTURE WAS PRESENTED BY CORADCOM, DIR, SEI. HE PRESENTED
THREE ALTERNATIVES USING CONFIGURATIONS OF TCS AND TCT EQUIPMENT
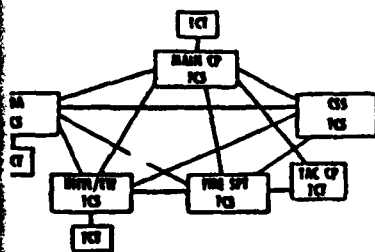
ALTERNATIVE 2

THAT COULD BE EMPLOYED TO PROVIDE NEAR TERM ECS^2 CAPABILITY. TIME PRECLUDES AT THIS TIME A DETAILED ANALYSIS OF EACH OF THE ALTERNATIVES, HOWEVER, ALTERNATIVE #2 SHOWN HERE WAS RECOMMENDED. ITS CHARACTERISTICS ARE ALSO SHOWN.

PAUSE

- TCS AT EACH OPFAC
- ADDITIONAL TCT AT
  -- MAIN CP
  -- AADCP
  -- CENI OPFAC
  -- TAC CP

AT THE CONCLUSION OF THE APPRAISAL, THE CDR, TRADOC, GEN STARRY, AND VCSA, GEN VESSEY, GAVE THEIR COMMENTS WHICH ARE TANTAMOUNT TO THE DECISIONS REACHED AT BAA V. A DETAILED TASKING DOCUMENT IS CURRENTLY BEING STAFFED WHICH WILL SPELL OUT SPECIFIC TASKS REQUIRED TO ACCOMPLISH THE ACTIONS REQUIRED BY THEIR GUIDANCE. IN RATHER GENERIC TERMS, HERE ARE THE MAJOR BULLETS WHICH SUMMARIZED THEIR COMMENTS.

CDR, TRADOC, COMMENTS

APPROVE ECS^2 AS THE ARMY OBJECTIVE COMMAND AND CONTROL SYSTEM
APPROVE CENSEI ALTERNATIVE #2 FOR NEAR TERM CAPABILITY
INSURE COMM TRACKS WITH AUTOMATION
TRY TO CAPTURE LATEST TECHNOLOGY
EVALUATE PAY-OFF BETTER THAN JUST TIME LINES

I KNOW THIS HAS BEEN RATHER FAST BUY MY PURPOSE WAS ONLY TO GIVE YOU A QUICK OVERVIEW OF THE MOST RECENT FORUM OF OVER 50 GENERAL OFFICERS CONVENED TO DISCUSS THE DIRECTION WE IN THE ARMY SHOULD BE HEADING IN THE AREA OF BATTLEFIELD AUTOMATION.

VCSA GUIDANCE

- APPROVED ECS^2 AS THE ARMY OBJECTIVE S1
- APPROVED CENSEI ALTERNATIVE #2 AS NEAR CAPABILITY
- USE AC^2VP AS UMBRELLA MANAGEMENT STRUC FOR ACTIONS

75

LTC JAMES E. GLEASON

LTC Gleason is a 1957 graduate of Boston College, with an AB degree in Economics. He was commissioned in the Regular Army, Field Artillery, and served in various field artillery, air defense artillery, and special forces assignments.

He currently serves as Chief, Army Command Control/JINTACCS Division, C^3I Directorate, Combined Arms Combat Development Activity.

SURVIVABILITY, MOBILITY, AND DISTRIBUTED ASSETS

H. S. Madoff

Harris Corporation
Government Communications Systems Division

ABSTRACT

New systems are emerging which greatly increase battlefield information availability. The threats to processing and communications elements, however, are evolving faster than present systems and architectures can respond. Mobility, as a means for survival, introduces a new set of requirements and considerations beyond the capabilities of many existing and planned systems. Distribution and internetting of processing and communication assets, coupled with high mobility, is seen as a means to counter the evolving threat. The implications of highly mobile distributed network elements will cause C^3I systems in the 1990s to inhabit a network architecture wherein communications are imbedded in the overall users mission needs. Moreover, for nodal survivability, equipment architectures will be distributed within local areas (such as command posts) to avoid loss of an entire node due to single element failure or destruction. The need arises to distribute network control and data bases throughout the battlefield network to attempt to equalize the workload (both human and machine) through the echelons, and to minimize the complexity of any single mobile element. The C^3I network and equipment architectures of the 1990s must also take advantage of existing and planned systems and equipments, while minimizing the logistics support burden and the cutover impact.

The intent of this paper is to examine the implications of mobility on existing systems, to postulate general tactical communications requirements for the 1990s, to illustrate the added impact of planned systems in the mobile environment, to discuss the implications of distributing battlefield assets in the mobile environment, and to postulate an approach to the C^3I architecture of the 1990's in a manner consistent with existing assets.

Introduction

Recent technological and tactical developments have expanded the capabilities and responsibilities of the battlefield commander. Improvements in target detection, precise geographical location, and ordnance delivery have increased our ability to engage large numbers of enemy targets without the commitment of large personnel resources. Hence, Force Multiplication has evolved as the concept of using technology as the lever in winning or containing conflicts against numerically superior forces. Adversary tactics, however, are evolving concurrently to nullify or offset these advantages by the use of countermeasures which include increased mobility.

Mobility raises the importance of the concept of "intelligence time," which is that time required by either side in a conflict to locate, target, and destroy an enemy concentration of assets. A highly mobile enemy can avoid

destruction by being able to move within the "intelligence time" limits of our ordnance delivery systems, and vice versa. A penalty to the concept of Force Multiplication arises in that the complexity and quasi-static nature of our technically superior ordnance delivery systems increases the probability of destruction by a highly mobile adversary. The net result is that future tactical commanders will require increased intelligence data, closer intra- and inter-service coordination of resources, and increased mobility.

The initial INTACS Study developed a cost-effective tactical communication system for the period 1976-1991. In the few years since INTACS, indications are that the C^3I needs of the 1990's will require systems heretofore described in science fiction movies and writings. ELINT and SIGINT systems are emerging which provide deep penetration past the FEBA and generate enormous amounts of data detailing enemy concentrations and maneuvers. Highly mobile ordnance platforms are being developed concurrently. To enable timely response to targets, specifically with the intent to "find-before-fire" or allow QUICKFIRE capability with TACFIRE, highly formatted targeting messages and/or graphics will need to be transmitted quickly through the network.

Two contradicting requirements appear to dominate the Army C^3I needs for the 1990's: the need to simplify the command and control activities for a highly mobile force network, and the need to rapidly manage and disseminate enormous amounts of diverse and complex data.

Evolving Communications Requirements

Figure 1 illustrates a simplified summary of the INTACS objectives for the 1980's, and the predicted objectives for the 1990's. The complexity and speed of response envisioned indicate the need for terse, pre-formatted message data to be delivered to and from units closer to the FEBA. Rapid situation reports (SITREPS) and position location information will be of the greatest importance to the battlefield commander and can be fully automated. Orders to units closer to

Figure 1.

the FEBA are also candidates for automation. Note the suggestion that Mobile Subscriber Equipment, namely MST's, or some variation thereof, could be deployed at BN and below for communications across BN or Company boundaries. This would allow Companies or Battalions to "patch" through adjacent units to the next higher echelon, providing enhanced communication survivability and command and control in the event of disruption of service to ones specified higher echelon. Figure 2 illustrates a case wherein the uppermost Companies are cut off from BN. By being able to "patch" through to the central BN, even if routed through an adjacent Company, positive command and control can be maintained until the uppermost BN capability is restored. Data base distribution and security issues arise which will be addressed later.

Figure 2.

The Consequences of Mobility

The evolving threat to our battlefield resources is being responded to by the requirement for increased mobility. However, our present network architecture does not appear to be able to keep pace with the high degree of mobility envisioned for the 1990's. The consequences of mobility as a means of survivability are best seen by example. Figure 3 illustrates a single thread through echelons of Corps and below for Main and Alternate Command Posts (CP), excluding artillery and support CP's. The intent therein is that as a particular CP is operating within the communications network, its alternate CP is moving from its previous position to a new position where it (the alternate) enters the

32798

3

UNIT	OPERATE	TEAR-DOWN/ MOVE/SET-UP	CASE 1	CASE 2
XXX	12 (HOURS)	4 (HOURS)	1	1
XX	6	2	3	5
X	3	1	3	3
II	1.5	0.5	3	5
I	0.75	0.25	3	6
P_{MAINS}			0.024	0.003

$$T_{UPDATE\ (MAX)} = \begin{cases} 0.25\ (HOURS) & , 3\ COMPANIES \\ 0.1875 & , 4\ COMPANIES \\ 0.15 & , 5\ COMPANIES \\ 0.125 & , 6\ COMPANIES \end{cases}$$

A0485-1AFCEA

Figure 3.

network and allows the other CP to move. For illustrative reasons only, intelligence times have been assumed for Corps through Company of 16, 8, 4, 2 and 1 hour(s), respectively. Again, for illustration, the single node time-line availability was assumed as 75 percent (i.e., 75 percent operating, 25 percent tear-down/move/set-up). From this starting point, one can determine that network changes, as a result of nodes entering and exiting the network, can occur as rapidly as once each 7.5 minutes (for the case of six companies per battalion), as averaged over several hours of sustained activity. Moreover, the two cases shown in Figure 3 for unit complement indicates that the probability of all "Main" CP's being in the active network at any one time, for the intelligence times given, are 0.024 and 0.003, respectively. For cases where routing indicators (RI) and/or telephone numbers change between main and alternative CP's, the message or circuit switched networks will be in a state of routing flux in excess of 90 percent of the time.

For the simple case of Main and Alternate CP's, the quick network exit and entry requirements may be manageable. However, as new systems become fielded

32798

the FEBA are also candidates for automation. Note the suggestion that Mobile
Subscriber Equipment, namely MST's, or some variation thereof, could be deployed
at BN and below for communications across BN or Company boundaries. This would
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the event of disruption of service to ones specified higher echelon. Figure 2
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CP is operating within the communications network, its alternate CP is moving from
its previous position to a new position where it (the alternate) enters the

and integrated into the communications net, the number of distributed nodes at any particular echelon will increase drastically, and the network management requirements will increase accordingly to coordinate hundreds of network control updates per hour.

The Impact of New Systems

The battlefield commander's needs for increased timely intelligence data are being addressed by the development of the All Source Analysis System (ASAS), and the internetting of ASAS data with Tactical Operations Centers (TOC), TACFIRE, and other systems such as the TSQ-73 FIREFINDER and the Ground Processing Centers (GPC's) for sensor systems like PLSS, SOTAS, GUARDRAIL, etc. The functional connectivity of these systems, at Corps and Division levels, is illustrated in Figure 4. Overlaying the survivability/mobility network implications and distributed C2 objectives, one sees a proliferation of communications connectivity and an aggravation of the overall control needed to keep the topologically changing network functioning. Thus, while systems presently evolving for deployment in the 1980's and 1990's time frame will provide more situational data to the battlefield commanders, they will be adding to the present communications throughput and control burdens. Distributed processing and control may provide the required survivability, but may also require drastic architectural changes in both connectivity and network control.

Figure 4.

Moreover, as management of the distributed assets become more complex and require faster network control response, communications personnel will not be able to respond in a useful manner without 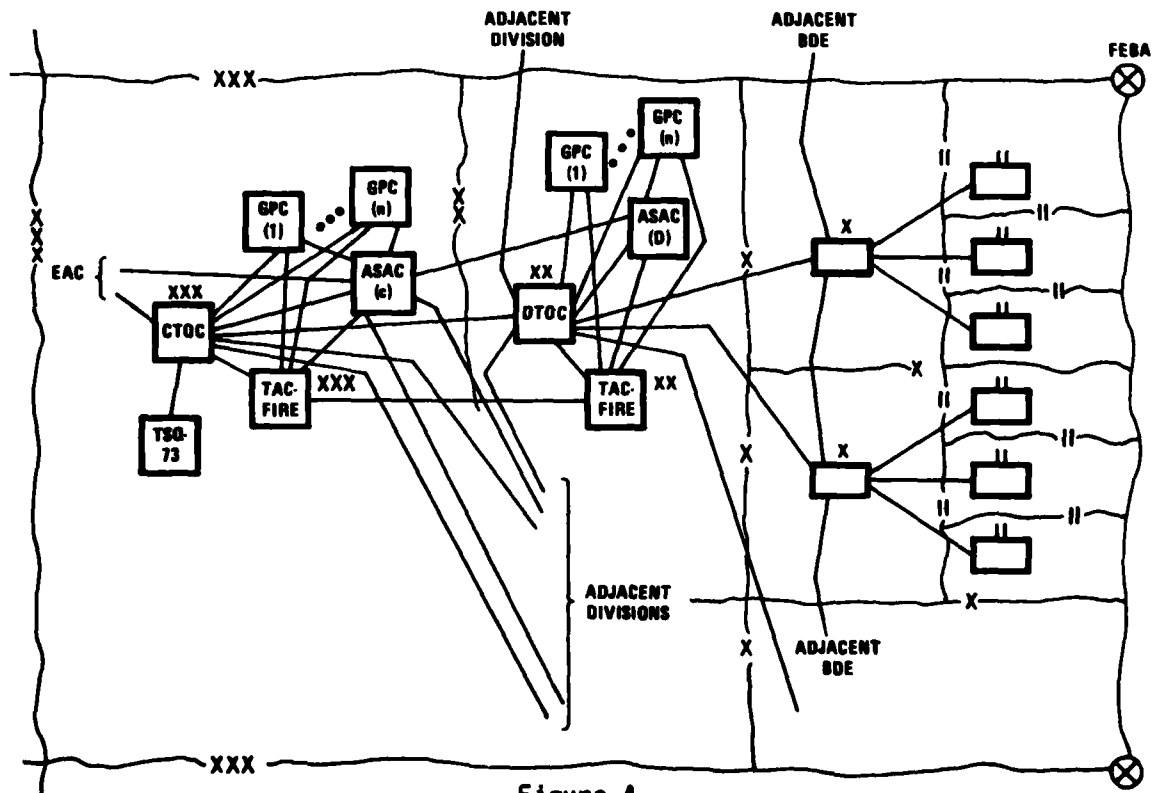ADP enhanced or possibly fully automated help. The man/machine interface into the communications network will be similar to the battlefield commanders situation displays, but concerned with node

status, line quality and availability, addressing for messages or circuits, etc. Normal network entry and exit will become computer controlled, with spoof-proof challenge/response techniques developed to avoid communications compromise, and only non-normal or emergency situations routed to the operators. Decentralization of communications, as in packet networks, helps this somewhat in that a local problem can be handled by a local operator with a limited purview, rather than a centralized operator with hundreds of nodes to control. The homogeneity of a packet approach allows for a unified operator control methodology to be imposed such that simpler actions can alleviate network difficulties.

Distributed Assets and Decentralized Control

Decentralized processing requirements are a driving factor in the evolution of distributed networks, such that any node within a distributed network benefits from processing and data access resources far in excess of those resident at the particular node. While the benefits of such a system are evident (i.e., less complex highly mobile nodes linked in pseudo-symbiotic relationships), certain network aspects which have been set for the quasi-static backbone network demand renewed interest and scrutiny. For example, if a Communications System Control Element (CSCE) is to be located at DIVMAIN (Ref. INTACS), if message data (conventional or otherwise) is projected out toward company level, and if mobility leads to network routing changes on the order of every minute or less, it is not clear that the currently envisioned CSCE could meet the requirements of a distributed, changing network topology of this nature. Distributing CSCE functions in a series of nested subnetworks could alleviate the load on any one control segment (e.g., keep the product of lines serviced and response time constant through the echelons). By distributing network control, one could also more easily accommodate the tighter security and authentication requirements needed to keep the network from being penetrated by hostile "listeners" or "spoofers." Moreover, a series of subtle yet effective measures beyond COMSEC may have to be incorporated to avoid "spoofers" from disrupting network operation. For instance, a captured communications node could be able to continue communication and have the safe means to notify the net or subnet supervisor of compromise. Thus, knowledge of infiltration can be made available, real data transmission can be circumvented, and counter intelligence techniques can be applied.

For distributed C^3I networks in the 1990's, communications will no longer be distinct with clearcut boundaries, because data base interactions will be both mission specific and network-specific. Authentication and error control will take on increased importance to avoid compromise of position or tactical data, and to avoid accidentally or overtly erroneous data and/or network control to influence the network. Address (RI and telephone number) assignment strategies will evolve to keep pace with the overall mobility and network entry/exit requirements. The delimiting of type and grade of service at echelon boundaries will take on added importance as tactical communications become increasingly embedded in the overall C^3I architecture.

The decentralization of the command and control will include networks within an echelon as well as local area networks within a CP. The ostensible objective of distributed command and control assets in a CP is to preclude loss of the CP capability in the event of a single element failure. A secondary objective is potentially easing the logistics burden by utilizing common and/or modular hardware, and a unified software language. The Army Command and Control Master Plan (AC^{2}MP) describes a sample distributed C^2 Executive system with functional redundancy for survivability. In the battlefield context, the sample distribution utilizes 10 interconnects and provides 100 percent functional performance for the loss of up to two nodes, as shown in Figure 5(A). Because of

32798

mobility requirements, the number of interconnects can adversely affect set up time, tear down time, and logistics support. An alternative, shown in Figure 5(B), is useful for comparison. By choice of an appropriate processing system architecture for the distributed nodes, 100 percent functional performance can be achieved for the loss of up to four nodes by software reconfiguration of the surviving nodes to absorb some or all missing functions. The throughput performance degradation of the alternative is faster than the original configuration, but the number of interconnects is less by half. Also, the alternative nodes are logistically identical including software complement, with the distinct functional identities set at set-up time.

(A)

NO. INTER-CONNECTS	NODES LOST	FUNCT. PERF.	COMM. "LINES" REQ'D
	1	1.0	2
10	2	1.0	3
	3	1.0-0.8	4
	4	0.6	5

(B)

NO. INTER-CONNECTS	NODES LOST	FUNCT. PERF.	COMM. "LINES" REQ'D
	1	1.0	2
6	2	1.0	3
	3	1.0	4
	4	1.0	5
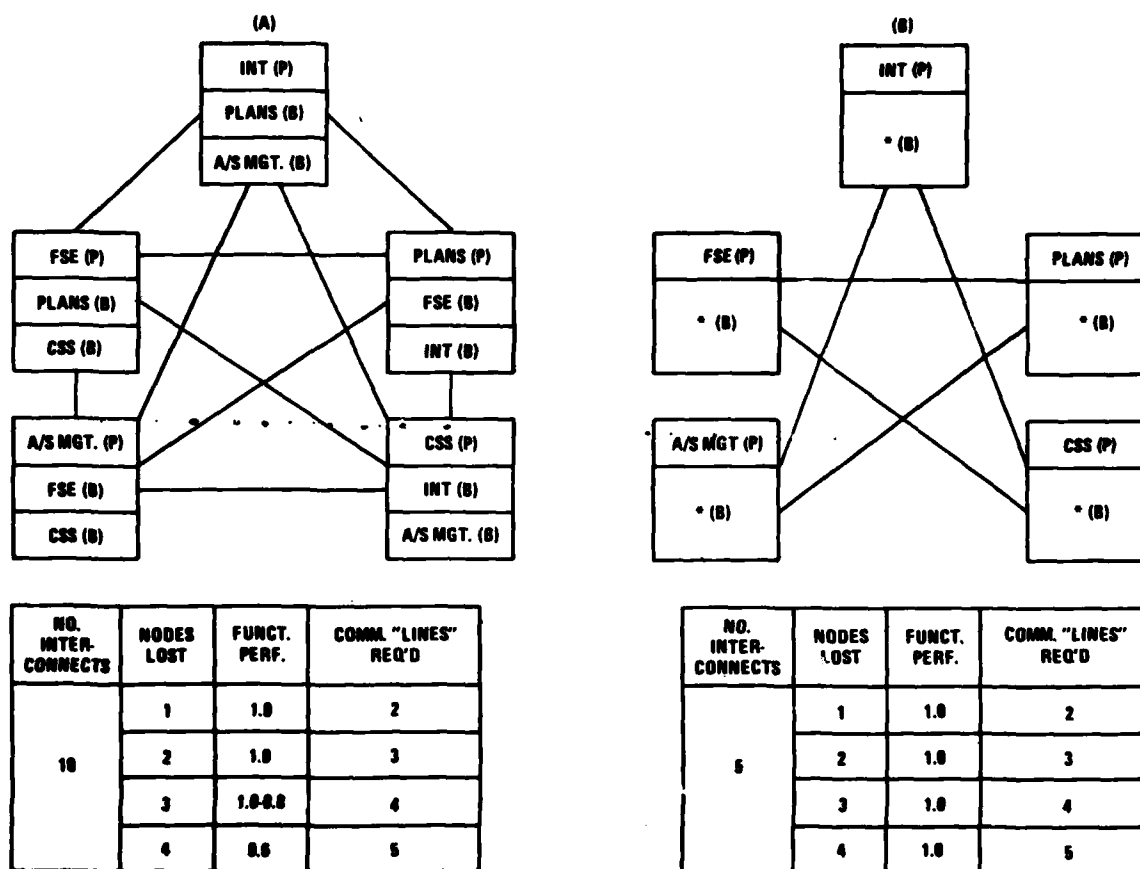
*NOTE: SOFTWARE RECONFIGURABLE
WITH APPROPRIATE "TASK"
AND "MISSION" MODULES   A0485-9AFCEA

Figure 5.

Addressing the Problems of Distributed Assets

INTACS is conceived as an on-going effort to refine Army communications requirements as tactics and technologies evolve. The challenges of the postulated 1990's battlefield environment and distributed assets may be well served by a parallel effort examining communications from a purely top-down, structured approach as alluded to in Figure 6. To incorporate the intelligence fusion concepts and reflect the mission responsiveness of future Army communications

*NOTE: CROSSLINKS FOR SURVIVABILITY

A0485-6AFCEA
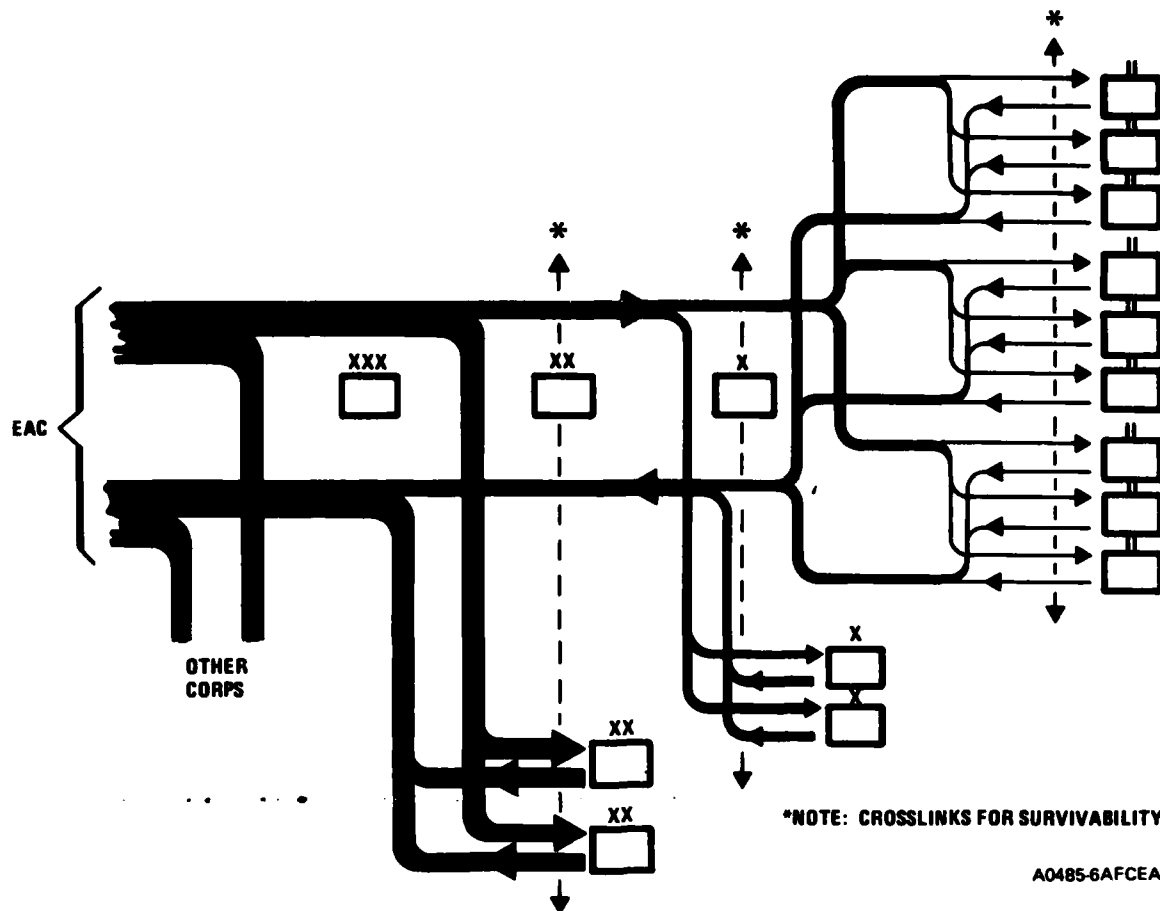
Figure 6.

networks, a heuristic approach based on the overall "products" of C^3I might be the most useful. These "products" are both offensive and defensive in nature, namely:

- Offensive

    - Accurate and timely delivery of ordnance
    - Positive control and coordination of position
    - Accurate and timely intelligence and assessment receipt and dissemination
    - Adequate and timely force and logistics support

- Defensive

    - Survivability by mobility and denial of positions and strength information
    - Positive control and coordination of position
    - Accurate and timely intelligence and assessment receipt and dissemination
    - Adequate and timely force and logistics support

The commonality exhibited should be exploited throughout any evolving architecture for the 1990's, and is summarized in a top-level manner in Figure 7.

3279B
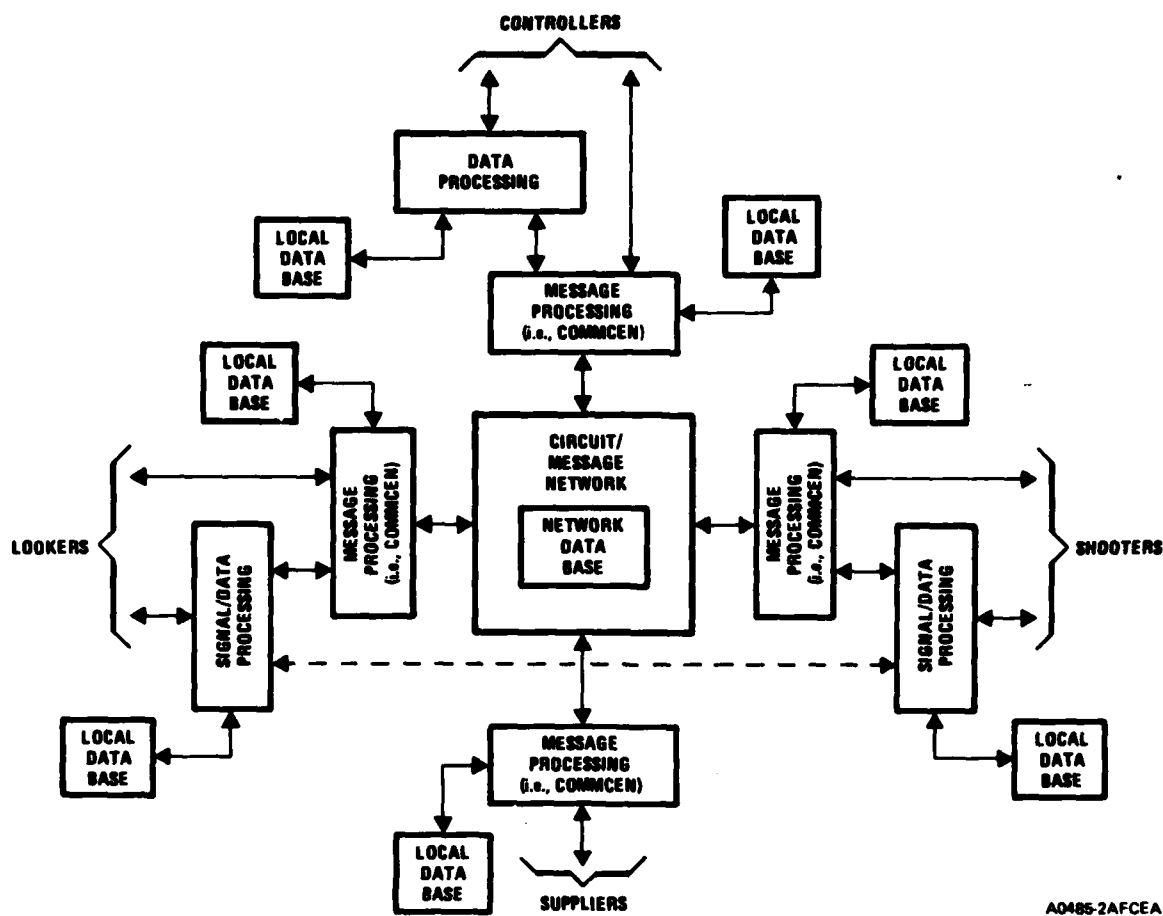
Figure 7.

Because of the diversity of tactical missions and limited defense spending, a shift to general processing and communication systems will be seen, with software "Task Modules" and "Mission Modules" tailored for specific applications. This generalized system architecture can evolve, after suitable analysis across mission boundaries, to maximize the use of the Military Computer Family (MCF) and Ada as a means to ease the logistics burdens of hardware sparing and repairing, and post-deployment software maintenance. Accompanying this will be increased automation of logistics and status functions to ease the real-time operator burden.

A general architecture can be envisioned for future TOC's, ASAC's, and other nodal elements requiring both communications and specialized processing, which is responsive to distributed networks, tolerant of technology insertion, and highly modular. Figure 8 functionally describes such an architecture which allows for both RED and BLACK external interfaces (both for communications and processing) within the appropriate security constraints, as well as three levels of internal interfaces. The Local I/O ports are useful for operator interfaces off-line storage devices, and other process-external devices and functions. For stacking (i.e., paralleling) processing assets for more external interface capabilities, e.g., more communications lines, more operator interfaces, etc.) wherein greater processing power is required, the "BUS A" extenders are designated; for stacking processing assets for greater data base and data manipulation capabilities, the

32798

BLACK
RED

"TASK MODULES"   "MISSION MODULES"

EXISTING & PLANNED TRANSMISSION MEDIA

SEPS & PATCH/TEST PANELS

REMOTE I/O
REMOTE I/O
REMOTE I/O
REMOTE I/O
LOCAL I/O
LOCAL I/O

"BUS A"

"CPU"
"CPU"
"BUS" EXTENDER
"BUS" EXTENDER

"BUS B"

"DATA BASE"
"DATA BASE"
"BUS EXTENDER"
"BUS EXTENDER"

A0485 4AFCEA
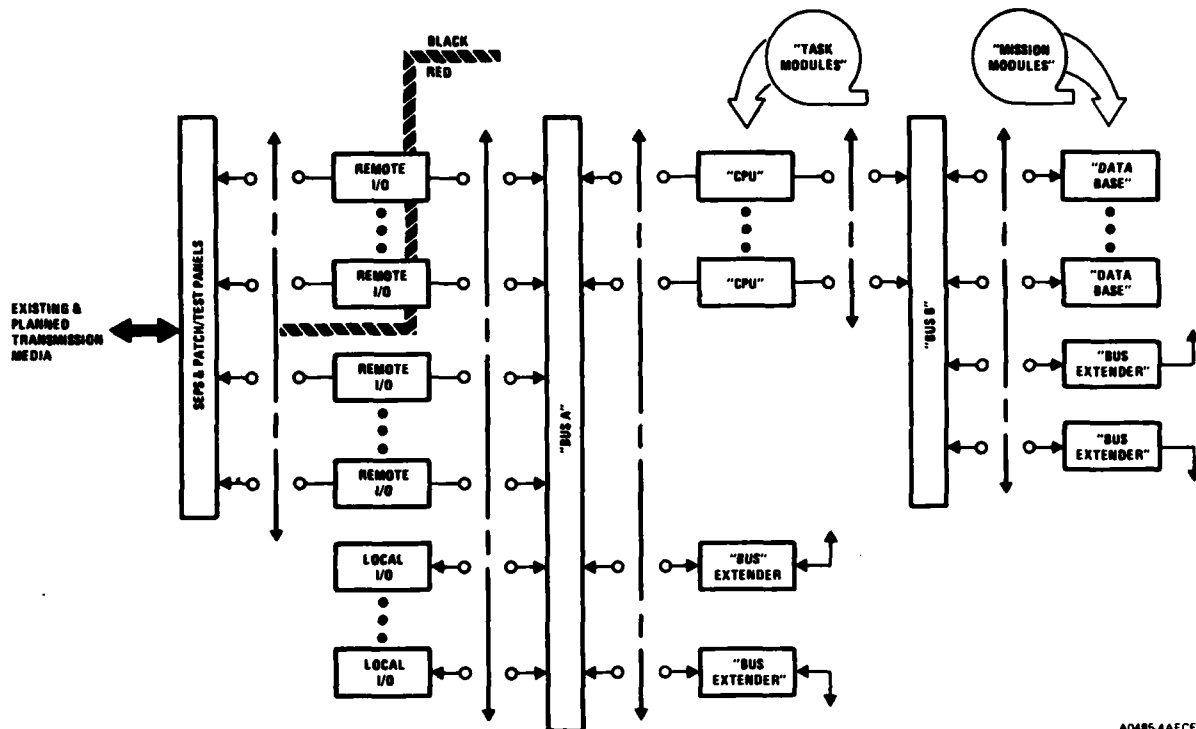
Figure 8.

"Bus B" extenders are designated. Specification and maintenance of internal interfaces can allow for technology insertion at all levels (i.e., I/O, "CPU", and "DATA BASE") within size, weight and power constraints. This is not inconsistent with technology trends since processing power and memory densities have continually increased within fixed physical and power boundaries.

Conclusions

Increased data requirements, faster and broader communications, and increased mobility lead to increased processing capabilities, diversified and flexible connectivity, and a general decentralization of the command and control structure. While seemingly a conflicting set of needs, operational and architectural upgrades could respond to these needs, and be expanded upon to evolve into future system, hardware and software developments. A growable architecture, as was depicted in Figure 8, can be responsive to the data density distribution in future Army C^3I networks as well as the need to segregate, periodically update, and (as required) expand, contract and even interchange data bases. This is consistent with the C^3I commanders perspectives through the echelons, as depicted in Figure 9.

If a distributed architecture is envisioned to include networks as well as nodal elements, and sufficient care exercised in the top-down functional partitioning, technology insertion can be achieved wherein increased processing capabilities can be realized without extensive system redesign. The net benefits accrued from microscopic upgrades of small subsystem elements which are manageable and well defined (in the functional, performance, and interface sense) are lower acquisition costs and reduced time to deployment. This is graphically illustrated in Figure 10.

32798
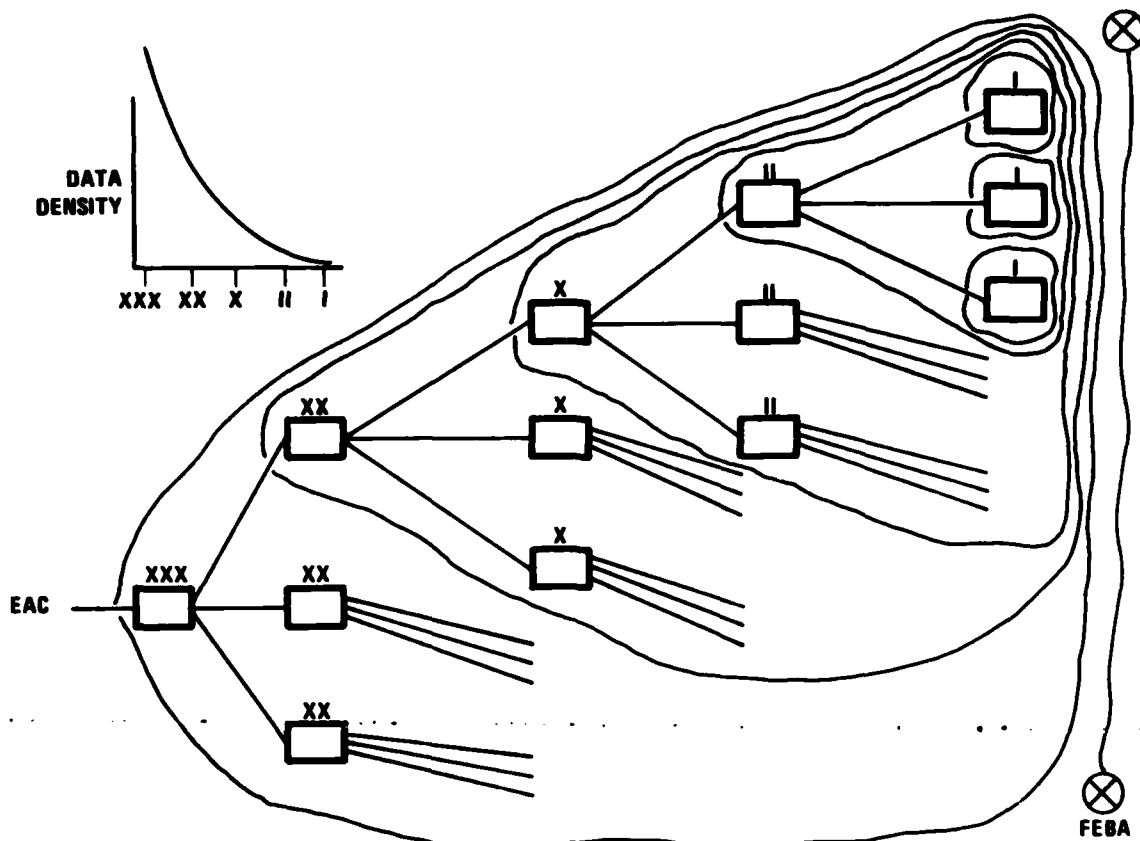
Figure 9.

A0485-10AFCEA

SYSTEM REDESIGN VERSUS
ARCHITECTURE ADAPTATIONS
(REVOLUTIONARY OR EVOLUTIONARY)
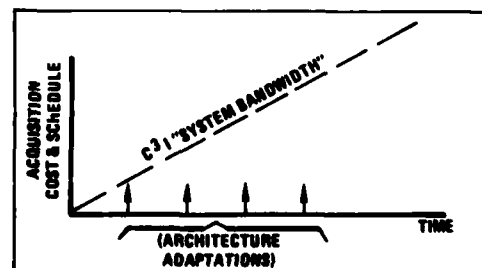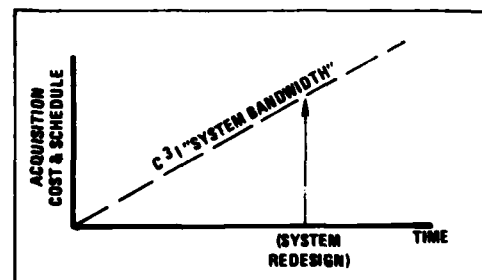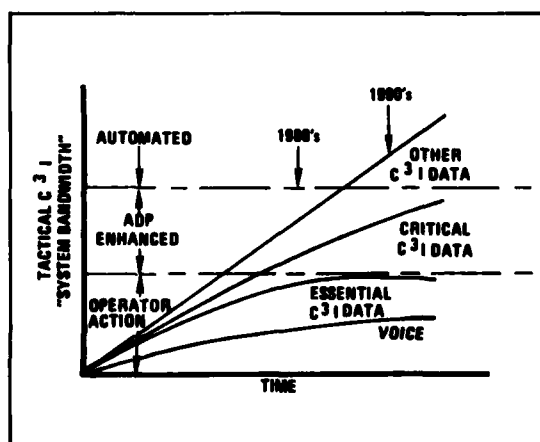
A0485-8AFCEA

Figure 10.

Several important aspects of distributed assets exist which will require special attention in the coming years. Interoperability has always been a difficult objective within US services as well as NATO. Perhaps distributed processing and control will allow for simpler, more easily controlled interface and interoperability at a variety of echelons, allowing quicker joint reactions to front-line activities.

Existing communications systems and architectures have been a long time in the making, and the potential impact of decentralized control could have a serious negative impact on communications unless preparation and training begins early. A positive factor is the homogeneity of distributed assets and decentralized control, a characteristic which will tend to equalize the workload throughout the echelons in terms of activity and operator skills.

Finally, the avoidance of traumatic impact to in-place systems is of the upmost importance. The threat of a mobile adversary appears to dictate beginning any upgrade near the FEBA, proceeding upward toward Corps. However, the larger purview requiring enchanced processing and decision-making capabilities resides in the upper echelons. Regardless of where in the command hierarchy the future C^3I architecture begins its integration, the care with which applicable existing systems and equipments are utilized will aid in reducing the cut-over impact and in effecting rapid acceptance and full exploitation.

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3279B

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ADA AS A DESIGN TOOL FOR FUTURE C^3 SYSTEMS

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ABSTRACT

The design of the Ada programming language which has been under development by the Department of Defense for the past several years has just been completed. Implementations are in progress and the years ahead will show if the promised expectations are realized. In this paper we review these expectations and discuss the two most innovative facilities in Ada and how they should impact future C^3 systems.

Studies conducted for the Department of Defense in 1973 and 1974 concerning the costs of software being procured by the DoD (costs that were very high and increasing at an alarming rate) showed that the most serious software problems were associated with what are referred to as "embedded computer systems." Command, control, and communication systems form the prime examples of such systems.

These concerns, which also included concerns about the quality of the software being procured (which was another equally serious problem), resulted in some major initiatives by the DoD, one of these resulting in the Ada Language. Since it was determined that the greatest potential benefits could be obtained by concentrating on the problems with embedded computer software, and since it was further determined that a serious problem existed in programming language usage in this application area, a DoD-directed tri-service working group was established. The mission of this group, which is called the High Order Language Working Group (HOLWG), was basically meant to be one of standardization, but it also included making available the most appropriate languages and supporting tools for use in developing embedded computer system software for the DoD. During the most important years of its existence the HOLWG was chaired by LTC William Whitaker representing the DoD. Also during this critical period, Dr. David A. Fisher, then with the Institute for Defense Analysis, was the group's chief technical advisor, and the main architect of the requirements document that resulted in the Ada Language.

Although, even at that time the use of high-level languages for embedded computer software was widespread, much (and perhaps most) such software was still developed (and hence maintained) in machine-level languages. Besides the readability of such code being very poor, making modifications to machine-level code is as frustrating and error-prone as any imaginable endeavor. Obviously, the unnecessary use of machine-level languages for embedded computer software was a factor contributing to the DoD's software problems.

91

Even when such software is programmed in higher-level languages, serious problems still existed. At the time the HOLWG was formed (Jan 1975) there was no control on the usage of languages for these applications. It was not rare for a major project to begin by designing its own high-level language, or at least modifying an existing language to an extent that in effect a new language was created. These would be no small undertakings. Programming support capabilities would also be needed including translators, development tools, testing aids, as well as host operating systems and special purpose executives. Such costly duplication obviously diverted from the effort of developing the application system itself. The cost of developing such language systems almost always meant that only the most primitive programming aids could be afforded. Finally, having systems tied to such special purpose language systems would mean unnecessary further ties of maintenance to the original developer. The large number of duplications of these essentially similar language systems (across the services and even inside any one service) obviously was another contributing factor to these high software costs.

Additional problems caused by using different languages for essentially similar tasks are:

-the research problems associated with embedded computer software are scattered and diluted due to a resulting lack of focus,

-the lack of communication and technology transfer among software practitioners working with different language systems.

One of the first early definite steps taken was to place some controls on the free use of programming languages in the DoD was the issuance of DoD Directive 5000.31. This is a small list of "approved" high level languages that can be used to develop new embedded computer application programs supported by DoD funds without getting approval. The use of any other language not on this list must be justified, and such justification would have to show benefits over the life-cycle of the project and not just development savings.

Embedded computer software is often very large, long lived, and subject to a great deal of modifications and improvements during its lifetime. It is not unusual for revisions to be of the same order of magnitude as the original development.

The reliability of such software is usually critical, it being essential that such systems continue to operate in the presence of faults in the input information, in operator procedures, as well as in the software itself. Such software must interface to a great diversity of input-output devices including control signals, analogue

devices, and sensor monitorings. Such software must support the handling of physical and logical concurrent system activity. It must also be capable of responding to critical timing problems, i.e., service interrupts often have to be handled within critical time periods to avoid disasterous consequences.

All of this, and more, resulted in the requirements specification that guided the design of Ada.

A summary of the major requirements is:

-A capability of aiding the process of producing reliable, robust software, i.e., software that is correct and capable of operating in the face of various kinds of adverse conditions.

-A capability of aiding in the development of modifiable software, i.e., software capable of being extended, changed, and improved in a controlled rational manner.

-A capability of handling logically concurrent processes that are implemented either on a uniprocessor or multicomputer system.

-A capability of interfacing with a wide variety of low-level I/O devices.

-A capability of interacting with real-time clocks to.control devices in response to time constraints.

The following remarks might help place the Ada project in some perspective:

-the entire history of high-level languages (if we start from original FORTRAN in 1957) spans only twenty-three years,

-just about all the programming languages used for DoD embedded computer software is based on the technology of at least twelve years ago.

-the field of research on programming language design is very active and many important new advances have been made over the past twelve years.

The Ada language project represents a major attempt at technology transfer. The language contains many exciting facilities that will be new to most of the user community. But each facility comes from the research community well-tested and well-understood.

Although such facilities as the exception-handling mechanism, the library facility, low-level I/O, generics, and even numerics all represent very important advances, it is the area of program structuring or modularization and the facilities for dealing with program concurrency that represent the most important and interesting new facilities incorporated into Ada.

Structuring the design of an embedded computer system so as to aid in the maintenance process can give enormous benefits in decreasing both costs and frustration levels. Just about every system will require modifications, corrections, and improvements (this is what maintenance means), especially after the initial design, and there are important contributions that a programming language can make to facilitate this. The most important modularization facility in the Ada Language is packaging. By means of which a system can be structured into interacting units in such a way that each unit is divided into two parts: a specification (or visible) part, and a body (or hidden) part. The specification parts contain the data types, variables, constants, operations, and procedures needed by system units in interacting with other system units. All implementation information that is not needed by other units is placed in unit bodies and is inaccessible anywhere in the system outside the body itself. This inaccessibility is enforced by the semantics of the Ada Language, i.e., by the compilation process. Provided the specification of a unit does not change, a body can be redesigned and reimplemented without causing effects on system behavior, except for possible performance changes. Even if system modifications require more substantial changes than to bodies along, the packaging feature can give the system a structural clarity that can help facilitate such system redesign.

The modularity facilities offered by the Ada Language go far beyond packaging. Each unit can, for example, be separately compiled, and the languages checking facilities go across separately compiled boundaries exactly like they go across all unit boundaries in the language. The tasking facilities are almost as useful and as important as packaging for system modularity. In preliminary Ada, the term module was used for either a package or a task, and although the terminology has changed, the fact remains that the task is an important modularization facility.

Ada tasking is with little doubt the most interesting facility in the Ada language. It offers the system programmer a facility for dealing with logical and physical system concurrency in the language. System concurrency is an essential fact in embedded computer systems and most of the current military languages require that the system designers in effect must either build all the mechanisms required in each application, or use pre-existing operating system mechanisms that may not fit the current application too well. Not only are these facilities available in the language itself (as opposed to being in back-up systems to the language), but they exist at a level that matches the user-oriented spirit of the rest of the language. The programming of intercommunicating concurrent tasks is usually the most

94

difficult kind of programming (i.e., the most complex and error-prone of all kinds of programming).

Current research indicates that distributed systems (multicomputer systems for example) offer much hope for great improvements in system efficiency, expandability, and especially system robustness. By this latter term we mean systems that can continue to operate in the presence of adverse external conditions or faulty conditions internal to the system. For example, systems that can continue to operate when parts are disabled. Ada's tasking can be implemented both on uniprocessors (just about all of the early implementations will be for uniprocessors) or non-uniprocessors. This possibility makes Ada of great interest to the research community working multicomputer system development.

BIOGRAPHICAL SKETCH

Dr. Amoroso has been involved with research and development in digital computer technology at Ft Monmouth for nearly twenty-three years. His contributions have ranged from the abstract and highly theoretical aspects of computer science to its very practical engineering side. Dr. Amoroso has published over a dozen refereed papers, he has served as Army representative to the Defense Department's High Order Language Working Group that produced the Ada programming language, and is currently working on the design of fault-tolerant systems. Dr. Amoroso has also been involved in Computer Science education for over twenty years. He is currently an affiliate Professor of Computer Science at Stevens Institute of Technology.

HARDWARE/SOFTWARE ISSUES AND IMPACT
OF HOL IN FIELDING VLSI

B. H. Whalen
TRW DSSG

ABSTRACT

Programmable hardware will be pervasive in Army systems of the 1990's. Three types of programmable hardware are discussed here: mask programmable, micro programmable and software programmable. Parallel signal processing puts new requirements on higher order languages and their associated compilers. Suitability of the new DoD language ADA to programming VLSI signal processing hardware is discussed.

HARDWARE/SOFTWARE ISSUES AND IMPACT
OF HOL IN FIELDING VLSI

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INTRODUCTION

Programmable Hardware will be pervasive in Army Systems of the 1990's. This hardware includes computers, signal processors, and special functions. The increase in programmability is due both to needs and to technology. Programmable system elements provide greater flexibility and accuracy. The widespread introduction of digital Very Large Scale Integrated (VLSI) circuits enables digital systems to be smaller, cheaper and more reliable than their analog counterparts. However, the enconomics of VLSI dictate that digital systems be programmable so that a minimum set of circuits can be used in a maximum set of applications. This result is evident already in the civilian sector. Microprocessors now dominate industrial electronics.

Programmability is both a blessing and a curse. It provides the flexibility to respond to new tactics and weapons with systems which have a long operational life. Since long operational life is the rule for Army systems, flexibility is essential. The curse of programmability is that it tends to increase the need for highly skilled manpower and can also increase support and configuration management costs. These negative impacts are magnified by the increased turn-over rate of military personnel.

This paper deals with the issue of programmable systems, and ways to minimize their negative impact. The issue is a complex one because programmability can take many forms. It can be embedded so deeply in system hardware that its existence may not be realized. However its potential negative impact still exists.

I shall discuss the various forms of programmability and their implication. Next I shall discuss the role of higher order languages (HOL) and compilers in solving the support problem. Lastly, I will discuss features of the new DoD standard language, ADA, which may facilitate programs which are highly structured and maintainable as well as efficiently implemented in VLSI hardware

IMPLEMENTATIONS OF PROGRAMMABILITY

MASK PROGRAMMABILITY.

Any system with a set of selectable switch settings or options is programmable. The selection can be accomplished by setting bits in a read only memory (ROM) or by making connections through a contact mask for an integrated circuit (mask programming). Some ROMs themselves are mask programmed. In addition to ROMs there are two main classes of mask programmable integrated circuits.

The first type is custom programmable circuits. These are circuits which accomplish a limited family of functions which are selected by the contact mask. For example a number of communications functions can be realized by finite state machines.' These machines are easily implemented by shift registers with programmed feedback taps. Programming consists of selecting the taps and the operations to be performed in the feedback paths.

Pseudorandom (PN) sequence generators, key generators, and code synchronizers are examples of functions which are programmable in this way.

The second type of mask programming uses regular arrays of Boolean logic gates. By appropriate connections of the array any logic function can be realized as a sum of products or product of sums. The desired Boolean expression is first reduced to the fundamental form, called a prime implicant. An assembler can then generate the required contacts in the mask pattern.

These two techniques can be combined by adding a latched output register and feeding it back through another "or" matrix to an input decoder. The input decoder provides the input to the "and" matrix as a Boolean function of the feedback state and the inputs.

The resulting flexibility is sufficient to realize the logic of any general purpose computer and a several computers have been constructed using this technique. However, the programming and testing require very sophisticated support tools.

The size and arr.gement of this type of chip, as well as the structure of the input decoder vary from manufacturer to manufacturer. Therefore each variation must have a different set of support tools.

MICROPROGRAMMABILITY

The feedback programmable logic array can realize a very large number of finite state machines, depending on the feedback taps and the decoder logic. If these taps and logic are controlled by a control word, and that word is stored in read only memory, the chip is "microprogrammable". The program is a sequence of ROM addresses each of which results in a specific finite state machine. Each desired behavior option is stored as a word in the ROM. That option is executed by inserting the address of its control word into the ROM (microstore) decoder.

Normally, a number of parallel functional units are implemented in this way to build a computer or system. Each functional unit has its own control ROM. The microprogram for the system must address in parallel all of the ROMS. The addresses, when juxtaposed into a single long word, are called a horizontal microinstruction. This word may be as short as a few bits or as long as 300 bits, depending upon the machine.

The chance for error in programming at this level is quite high and obviously, support tools are essential. One solution is to encode the horizontal words into shorter words for all the bit patterns which realize useful functions. These shorter words are given mnemonics and an assembler is then constructed.

There is a practical obstacle to this in that almost all useful higher level instructions take several microcycles for each functional unit and the functional units may have to operate in a staggered pattern. Thus a vertical instruction may actually consist of pieces of several horizontal microinstructions.

One way around this obstacle is to insert delay registers in the various hardware units which precede the decoder ROMS. This permits a horizontal control word to be executed in the appropriate staggered pattern. A horizontal instruction can then be interpreted as all of the hardware operations required for a single piece of data. This technique is called data stationary microprogramming and simplifies the conversion from horizontal to vertical micorprogramming.

99

SOFTWARE PROGRAMMABILITY

Having worked on signal processing systems for sonar, electronic warfare, I have observed some common attributes of the software for these systems. Unfailingly, it is complex, interactive, asynchronous, data dependent, taxes to the utmost the machine resources, and subject to change.

These attributes present a formidable challenge to the software developer. Typical programming languages are assembly language, JOVIAL and FORTRAN. JOVIAL and FORTRAN speed up the programming process but don't improve the reliability very much. As a result, integration and testing are tedious at best. This condition is somewhat improved by the imposition of ad hoc coding standards and structured constructs.

PASCAL is a simple, highly structured language which both speeds up programming and improves reliability. If ad hoc coding standards are imposed, the reliability increases further. My experience has been that PASCAL systems are definitely easier to integrate.

DoD's ADA language is a descendant of PASCAL. It preserves the structure of PASCAL and adds a number of features which facilitate concurrent programming, or multitasking.

ADA provides the capability to program in functions. Functions cannot modify external variables but can only receive data and return values. This avoids the problem of illegal or unobserved modifications to common data, thereby removing the most dangerous source of program interaction and error.

ADA also provides for definition of generic program units. These units (packages, functions, and tasks) can have implementations which depend on the input and output data type. The compiler can determine the context from the data types and instantiate or invoke the appropriate code at compile time.

ADA is a strongly typed language and the type and object declarations are separated from the procedural or functional body. Further, ADA permits the definition of collections of resources (data structures and/or functions), called packages. The package specification (logical interface) can be separated from the package body. The package body can be hidden from users. Because of this users cannot make assumptions about package internals. Therefore replacement packages can be substituted without affecting other modules. These packages could be special VLSI hardware, as long as the logical interfaces are preserved and the compiler knows how to make the physical interfaces.

ADA's concepts of typing, type checking, and overloaded operators suggest the possibility of a type conversion compiler.

This compiler would be able to recognize that a type conversion (e.g., transpose of a matrix) is required to input data to a special operation. Rather than ignore the operator because of the illegal type, the compiler would invoke a type conversion function (matrix transpose) and reformat the data for the operator. With this capability, the compiler could use hardware operators as macros for functions that it recognizes in the code selection phase.

This concept leads to the related concept of hierarchical compilation. A VLSI ADA compiler should be able to recognize from the parse tree those macro functions which are executable in hardware. The compiler can link the data to the hardware. Other compiler phases such as code generation, data flow analysis and resource allocation should also be performed at this higher, macro level. Only

100

when the macro level compilation is complete should the normal compiler level be executed on the residual portions of the parse tree.

This higher level compiler must have a sophisticated type analysis and conversion facility or it will not be able to find and link the macro operators.

ADA's task synchronization and concurrency features are quite sophisticated and support table driven real time concurrent systems. The entry, accept and select commands facilitate the construction of device and input output queues for a sophisticated scheduling system. In addition, other task synchronization constraints can be imposed by the use of the block construct. All tasks which are to be concluded prior to an event can be initiated in a declaration block. The compiler will assure that the tasks terminate before the block is exited.

The select command facilitates the construction of conditional task servicing logic. It is similar to the case statement in that a set of conditional cases is specified. However, select statement causes a different task communication to take place for each condition.

Array structures are another ADA feature useful for signal processing. Many VLSI systems will be parallel array processors because that is one of the simplest ways to capitalize on the low hardware cost. Array operations will be performed in parallel and it is important to describe the input and output data efficiently. ADA provides this capability as well as the capability to perform functions on slices (contiguous segments) as well as rows and columns of arrays. This simplifies the programming of matrix algorithms, FFT algorithms, and sort algorithms. These three function types dominate many signal processing applications.

In order to utilize this ADA feature, the compiler must be able to use address generation macros efficiently. This is another area of compiler design. Most of the code generated by compilers is related to address generation. This function will be performed in hardware in VLSI processor. The compiler's code selector must select the appropriate hardware, macros when it processes array statements.

Changes in the hardware environment will require changes to the compiler. If these changes can be implemented via parameter tables, the compiler can be easily retargeted. To that end, the compiler should be highly modular so that the semantic analysis, the code selection and the data analysis can be easily modified.

In addition, the heuristics for code optimization should be readily alterable.

It is likely that one of the fruitful areas for improved resource allocation is the development of new, specialized allocation heuristics. For complex systems, it would be far easier to experiment with allocation heuristics than to optimize by hand.

In summary, the ADA language appears to be particularly well suited for VLSI signal processors. This is not surprising, because the language evolved from a very sound base of theory and practice. Computer Science has developed into a true science in the last ten years. Language theory is practical and well developed. The advantages of applicative programming (functional programming) have been rigorously demonstrated. Finite state machine theory has been applied to the computer construction of error free parsers (syntax analyzers). Graph theory techniques have been applied to data flow analysis.

As a result of these developments, a powerful language such as ADA can be specified and a compiler can be written with a modest effort. The principal areas where compiler design is still an art are in code generation and resource allocation. In addition, improvements in semantic analysis and data flow analysis are needed. If these efforts are successful, the result will be a new level of programmability and reliability for signal processing systems.

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ARMY C^3 IN THE 90'S

HARDWARE/SOFTWARE ISSUES
AND IMPACT OF HOL IN FIELDING VLSI

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DELIVERED TO FT. MONMOUTH AFCEA SEMINAR, 22 OCT., 1980

VLSI WILL INCREASE HARDWARE PARALLELISM
AS THE ONLY PRACTICAL MEANS FOR INCREASING
THROUGHPUT.

● MICROPARALLELISM

- PARALLEL IMPLEMENTATION OF FUNCTIONS
  WITHIN A CHIP

  E.G., LOOKAHEAD ADDERS
       MULTIPLIERS CONVOLVERS

  - TRADES COMPLEXITY FOR SPEED

● FUNCTIONAL PARALLELISM

- ARRAY OPERATORS, FILTER BANKS,
  FFT BANKS

● PROCESSOR PARALLELISM

- DISTRIBUTED PROCESSORS, NETWORKS,
  PROCESSOR ARRAYS

A HIGHER ORDER LANGUAGE MUST SUPPORT BOTH FUNCTIONAL AND PROCESSOR PARALLELISM

THE BASIC QUESTION: CAN PROGRAMMABLE SYSTEMS MEET OPERATIONAL NEEDS

SYSTEM SOLUTION

PROGRAMMABLE DIGITAL SYSTEMS

OPERATIONAL NEEDS

- LONG LIFE
- LOW COST
- FLEXIBILITY

- MINIMAL SUPPORT REQUIREMENTS
- RELIABILITY

THE ANSWER DEPENDS ON:
SYSTEM DESIGN
LANGUAGE DESIGN
SUPPORT TOOLS
DESIGNER DISCIPLINE
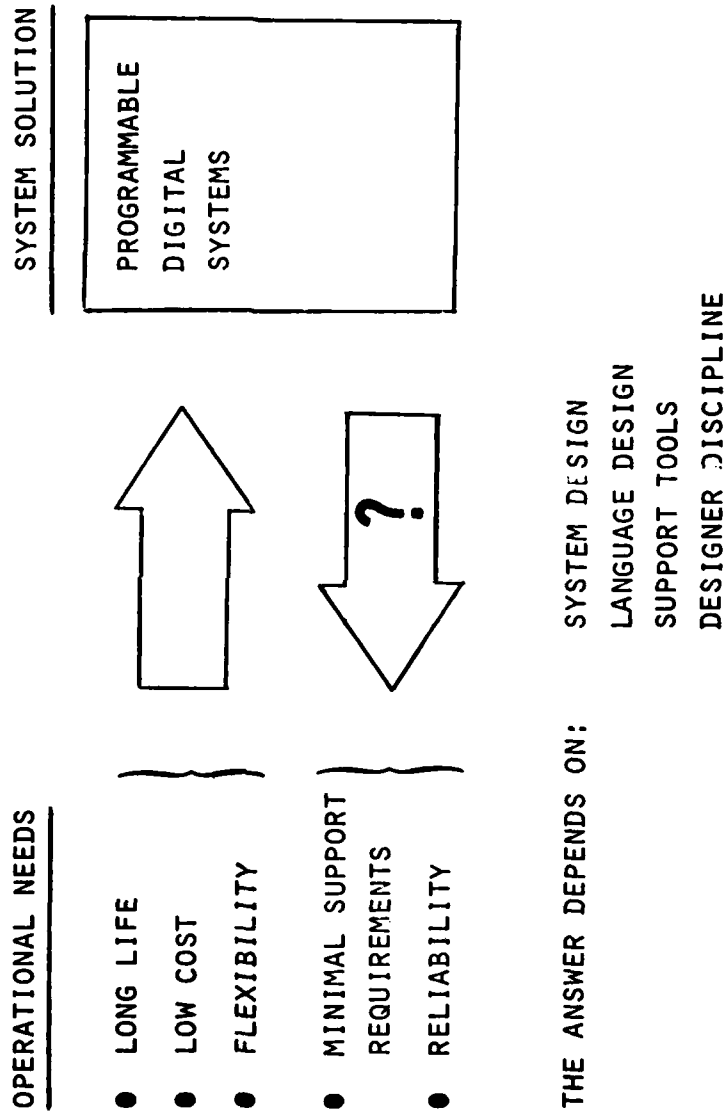
SUPPORT SOFTWARE MUST SUPPORT THE
ENTIRE LIFE CYCLE

- SYSTEM DEVELOPMENT

- SYSTEM DEPLOYMENT

- SYSTEM MAINTENANCE

- SYSTEM UPDATE

FEATURES MUST INCLUDE:

- DISTRIBUTED DEVELOPMENT

- HARDWARE CHANGE

- QUICK, RELIABLE REPROGRAMMING

- CONFIGURATION MANAGEMENT

- PERSONNEL TURNOVER

106

THERE ARE SEVERAL WAYS TO IMPLEMENT PROGRAMMABILITY

MASK PROGRAMMABILITY

● CODE GENERATORS

● GATE ARRAY CONTROLLERS AND INTERFACE ELECTRONICS

MICROPROGRAMMABILITY

● PARALLEL SIGNAL PROCESSORS

● INSTRUCTION DECODERS FOR COMPUTER EMULATORS

● MICROPROGRAMMED CONTROLLERS AND INTERFACE ELECTRONICS

VERTICAL, OR ASSEMBLY LANGUAGE PROGRAMMABILITY

● COMPUTERS

● DATA STATIONARY SIGNAL PROCESSORS

● DISTRIBUTED PROCESSORS

ALL THREE APPROACHES REQUIRE SUPPORT TOOLS.

COMBINATIONAL LOGIC CAN BE REALIZED
BY PROGRAMMABLE LOGIC ARRAYS

$E = F(A,B,C,D) = AB + \bar{A}C + BC + ACD$

ADD MATRIX

OR MATRIX
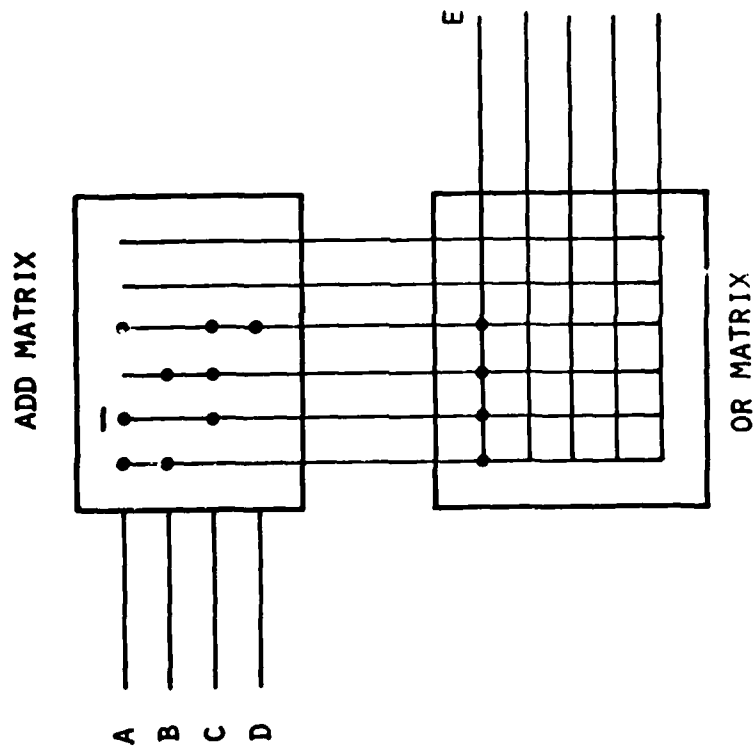
EACH EXPRESSION IS REDUCED TO A SUM OF PRODUCTS
CONTACTS ARE PROGRAMMED BY AN ASSEMBLER
PERFORMANCE IS VERIFIED BY A SIMULATOR
TEST DATA GENERATION IS AUTOMATIC

108

FINITE STATE MACHINES CAN BE REALIZED BY
ADDING FEED BACK FROM A DELAY REGISTER
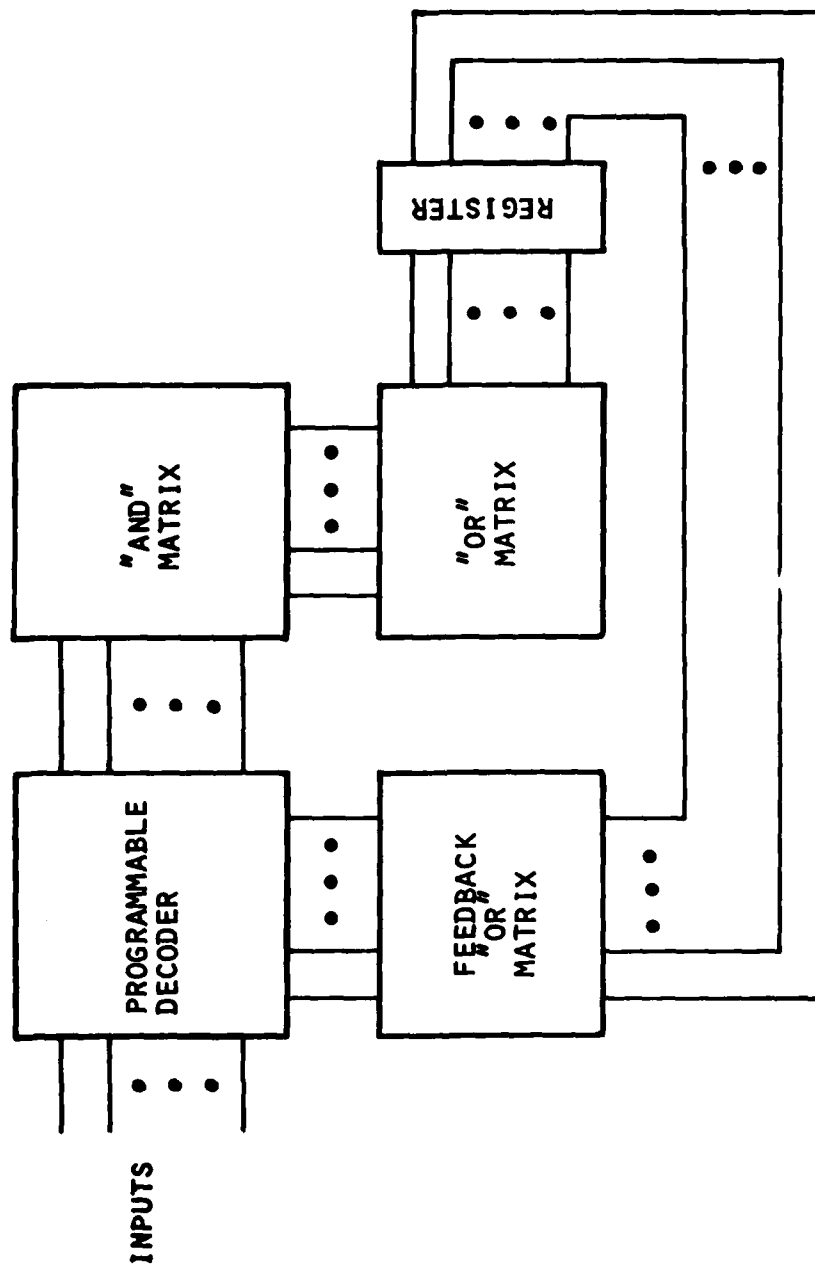
PROGRAMMING, SIMULATION, AND TEST GENERATION REQUIRE
SOPHISTICATED SUPPORT TOOLS.

109

MICROPROGRAMMING IS DIRECT CONTROL OF FUNCTIONAL UNITS

HORIZONTAL MICROINSTRUCTION

VERTICAL MICROINSTRUCTION

DATA STATIONARY

110
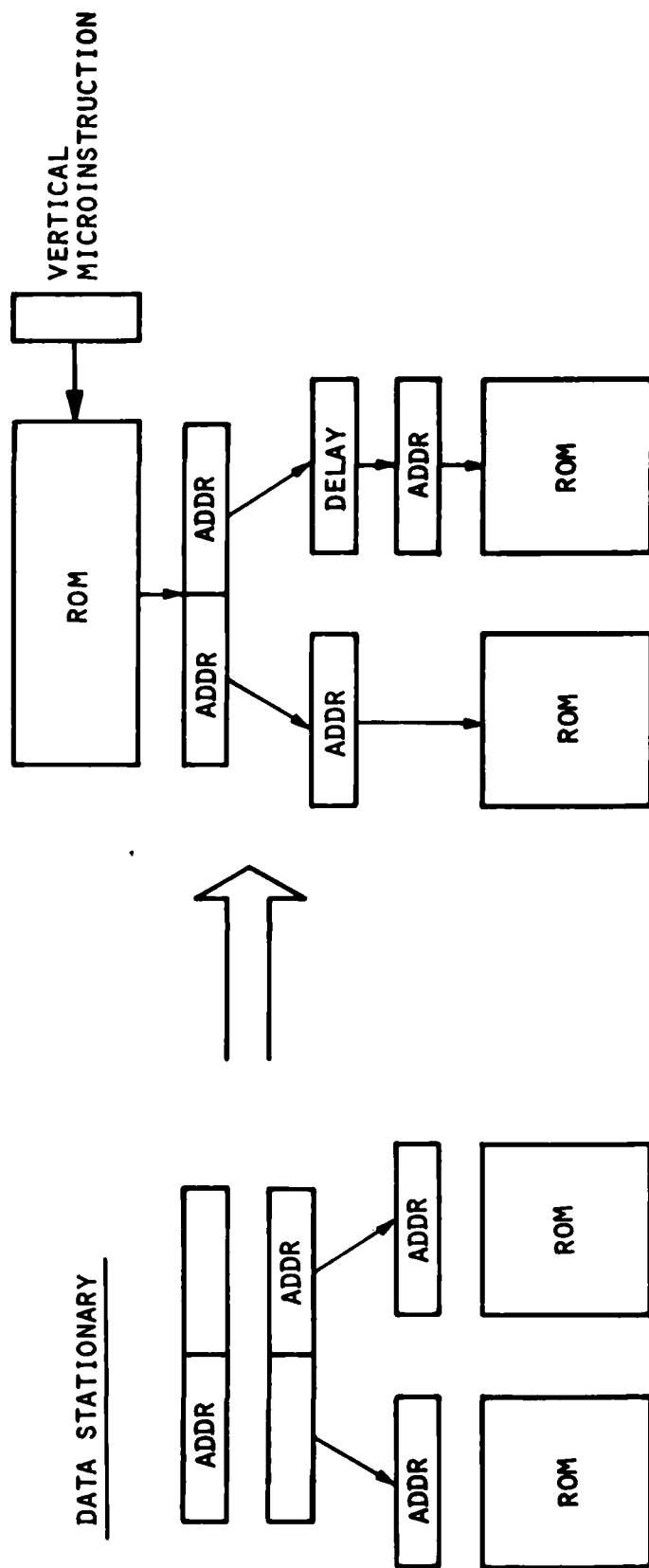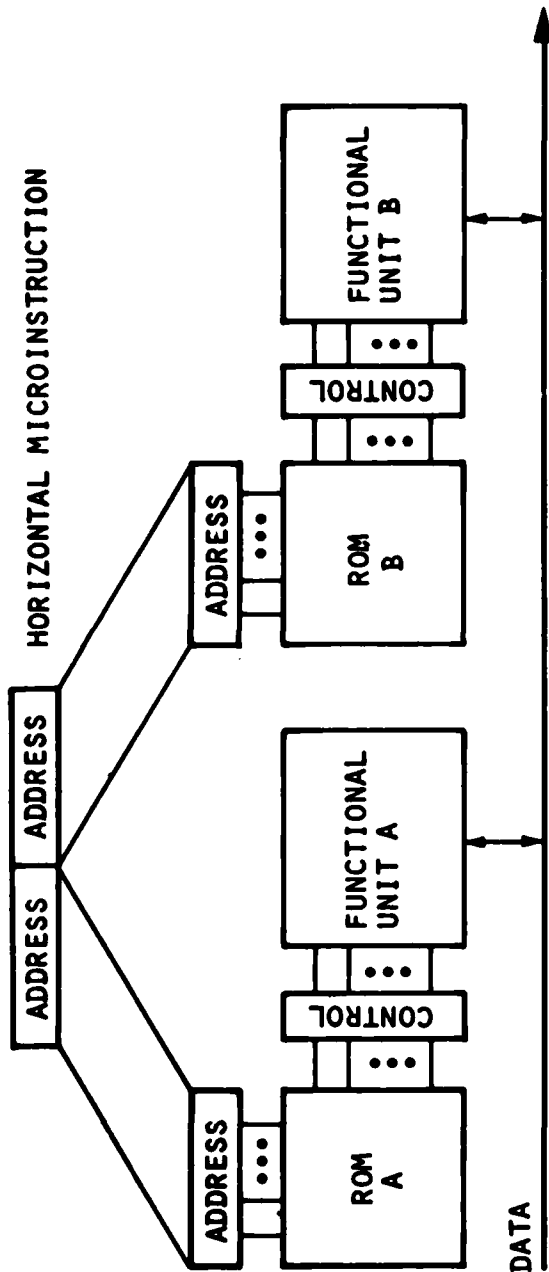
HIGHER ORDER LANGUAGE -
TWO BASIC LANGUAGE TYPES

IMPERATIVE (PROCEDURAL)

PROGRAMS CONSTRUCTED FROM PROCEDURES

PROCEDURES MODIFY GLOBAL VARIABLES, BASED ON COMPUTATION

HISTORICALLY USED FOR VON NEUMANN MACHINES

LESS PROVABLE IN TERMS OF RELIABILITY AND CORRECTNESS

REQUIRES CAREFUL TASK SYNCHRONIZATION

APPLICATIVE (FUNCTIONAL)

PROGRAMS CONSTRUCTED FROM FUNCTIONS AND FUNCTIONS OF FUNCTIONS

FUNCTIONS CAN MODIFY ONLY THE DATA OR PARAMETERS PASSED TO THEM

NEW APPROACH BASED ON IDEAS OF BURGE AND BACKUS

LEADS TO RELIABLE AND PROVABLE PROGRAMS

MAY BE LESS EFFICIENT

MAY LACK CONTROL FLEXIBILITY

SHOULD BE BETTER FOR FUNCTIONAL DECOMPOSITION

IMPERATIVE AND APPLICATIVE PROGRAMS
DIFFER IN THEIR ABILITY TO CHANGE DATA

APPLICATIVE

DATA IN → FUNCTION → DATA OUT

DATA IN → PROCEDURE → CHANGE IN DATA BASE
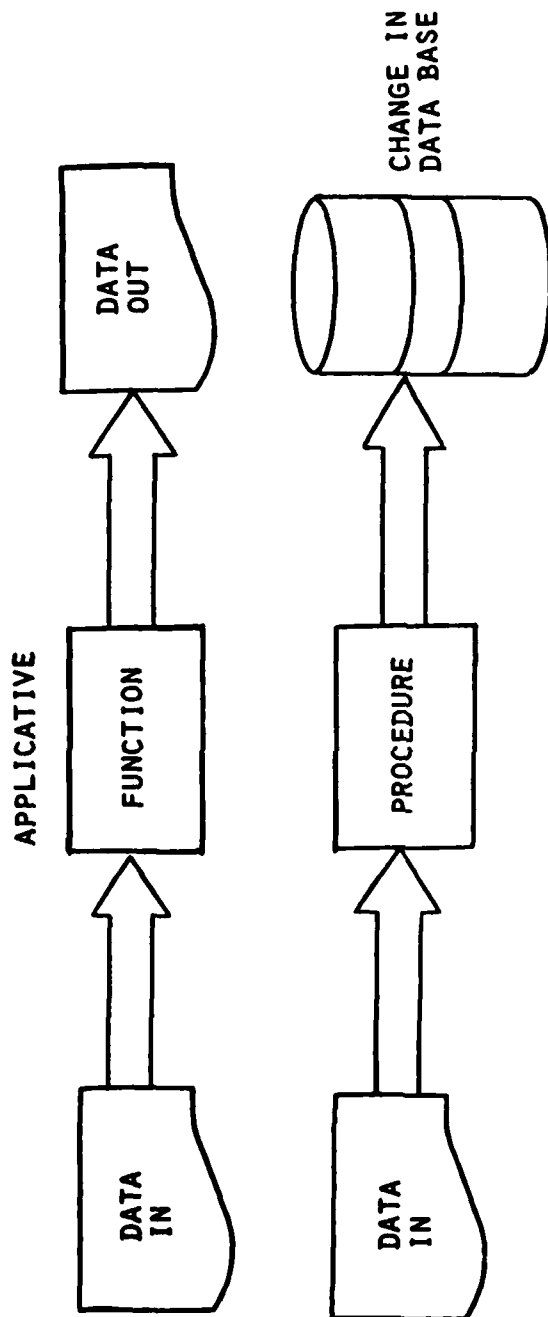
THE PROCEDURE CAN ALTER THE PROGRAM
CONTROL BY ALTERING THE DATA BASE.

112

A HIGHER ORDER LANGUAGE FOR SIGNAL
PROCESSING SHOULD HAVE SEVERAL
KEY FEATURES

- PERMIT APPLICATIVE PROGRAMMING

- PERMIT DISTRIBUTED DEVELOPMENT (SEPARATELY
  COMPILED PROGRAM UNITS)

- SEPARATION OF DATA STRUCTURE FROM PROGRAM STRUCTURE

- PERMIT DEFINITION OF NEW TYPES AND NEW OPERATORS

- PROVIDE FOR SEPARATION BETWEEN PROGRAM SPECIFICATION
  AND PROGRAM BODY

- PROVIDE FOR CONCURRENT TASKING

- PROVIDE FOR TASK SYNCHRONIZATION AND DATA TRANSFER

- PROVIDE FOR SPECIAL INSTRUCTIONS TO COMPILERS OF
  VARIOUS SYNCHRONIZATION

113

ADA PROVIDES USEFUL FEATURES
FOR SIGNAL PROCESSING

● DATA STRUCTURES   —   TYPES, OBJECTS
                                GENERIC TYPES
                                GENERIC PARAMETERS
                                RECORDS
                                DATA PACKAGES
                                OVERLOADED OPERATORS

THESE STRUCTURES FACILITATE THE DEFINITION OF RANGES AND DOMAINS
FOR FUNCTIONS AND FUNCTIONS OF FUNCTIONS. THEY PERMIT THE ASSIGN-
MENT OF OPERATOR MEANING ON THE BASIS OF RANGE TYPE AND DOMAIN
TYPE

● CONTROL STRUCTURES   —   CONDITIONAL BRANCHES FOR
                                GENERALIZED BOOLEAN OPERATORS

                                CASE STATEMENT
                                SELECT STATEMENT
                                FOR STATEMENT*
                                RENDEZVOUS/MAILBOX

* MAY NEED MODIFIED DEFINITION THROUGH PRAGMA

114

ADA PROVIDES USEFUL FEATURES

(CONTINUED)

- COMPUTING STRUCTURES

GENERIC FUNCTIONS   – COMPILER INSTANTIATES BY TYPE

GENERIC PACKAGES   – SEPARATION OF SPECIFICATION FROM IMPLEMENTATION

                           – IMPLEMENTATION KNOWN ONLY TO THE COMPILER

TASKS   – FACILITATES CONCURRENT PROGRAMMING

GENERIC TASKS   – CAN BE HARDWARE DEPENDENT

ENTRY AND ACCEPT STATEMENTS– INTERTASK COMMUNICATION

BLOCKS   – FACILITATES COORDINATED TASK COMPLETION

115
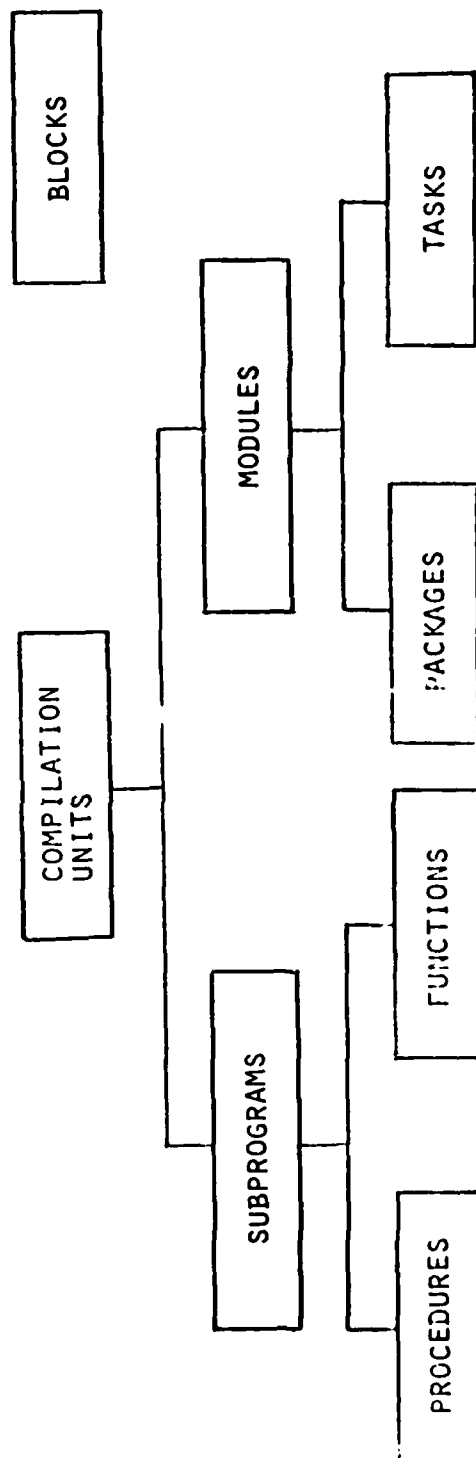
ARRAYS, AGGREGATES, AND SLICES

● ARRAYS OF ARBITRARY DIMENSION AND TYPE

● LITERAL ASSIGNMENTS ARE CALLED POSITIONAL AGGREGATES

● SELECTIVE ASSIGNMENTS ARE NONPOSITIONAL AGGREGATES

● SLICES ARE SUBSETS CORRESPONDING TO A SUBRANGE OF INDICES.
SUBRANGE MUST BE CONTIGUOUS

PROCEDURE   SLICES IS

v: ARRAY (1, .., 100) OF INTEGER

BEGIN

```
v(5,..,9)    : = (0,0,0,0,0)
v(15,..,19): = v(5,..,9)
v(6,..,10)  : = v(5,..,9)  ILLEGAL
v(6,..,10)  : = v(I,..J)    REQUIRES
                            RUN TIME CHECK
```

116

OTHER USEFUL ADA FEATURES

- PRAGMAS
  - SPECIAL COMPILER DIRECTIVES SUCH AS OPTIMIZE OR DON'T OPTIMIZE

- COMMANDS
  - TASK INITIATE
  RESTRICTED (PARAMETER ACCESS)
  PRIVATE   (DATA ACCESS)

- PARAMETER BINDING FOR PROCEDURES
  - (IN, OUT, IN OUT)

- TASK FAMILIES
  - PROVIDES MULTIPLE COPIES WITH BOTH COMMON AND UNIQUE PARAMETERS

117

ADA FEATURES ALLOW SIGNAL PROCESSING SOFTWARE TASKS

TO BE ALLOCATED TO SPECIALISTS

ARCHITECT:

PERFORMS FUNCTIONAL DECOMPOSITION

SPECIFIES STRUCTURE

SPECIFIES GENERIC ELEMENTS

SPECIFIES TYPES AND FUNCTIONS

SPECIFIES PACKAGES

SPECIFIES TASKING CONSTRAINTS

PROGRAMMER:

DEFINES OBJECTS

PROGRAMS FUNCTIONS AND PACKAGE BODIES

INTEGRATOR:

PERFORMS COMPILATION

ANALYZES ERRORS

PROGRAMS MULTITASKING

EVALUATES RESOURCE ALLOCATION

MAINTENANCE:

REPROGRAMS FUNCTIONS AND PACKAGES

MAY PERFORM INTEGRATOR FUNCTIONS

HIDDEN PACKAGE BODIES AND USE OF APPLICATIVE (NON PROCEDURAL)
TECHNIQUES MINIMIZE INTERFERENCE BETWEEN COMPILATION UNITS.

118

A SIGNAL PROCESSING COMPILER SHOULD
HAVE SEVERAL KEY FEATURES

- ACCOMODATE BOTH SEQUENTIAL AND PARALLEL MACHINES

- BE COMPLETELY MODULAR

- ACCOMODATE SPECIAL RESOURCE ALLOCATION ALGORITHMS

- PERFORM TYPE CHECKING AND TYPE CONVERSION

- RECOGNIZE SPECIAL INSTRUCTIONS

- BE MULTIPASS WITH EACH PASS EXTERNALLY CONTROLLABLE
  AND OBSERVABLE

- PROVIDE ERROR DETECTION AND AUTOMATIC CONTINUATION

- PROVIDE CROSS REFERENCING FOR ALL PROCEDURES, PARAMETERS,
  FUNCTION, DATA TYPES AND DATA OBJECTS

A MODULAR COMPILER STRUCTURE IS KEY

MODULE		OUTPUT
LEXICAL ANALYZER		TOKEN STREAM
SYNTAX ANALYZER		PARSE TREE (SYNTAX TREE) INTERMEDIATE CODE
SEMANTIC ANALYZER	*	TYPE CHECKS CONSTRAINT CHECKS TYPE CONVERSION
CODE SELECTOR	*	MAP OF PARSE TREE INTO INSTRUCTIONS
CODE OPTIMIZER	*	LOCAL IMPROVEMENTS LOOP IMPROVEMENTS
DATA FLOW ANALYZER	*	STRUCTURE IMPROVEMENTS VARIABLE REARRANGEMENT
RESOURCE ALLOCATER	*	MAPPING OF CODE TO HARDWARE
CODE GENERATION		MACHINE INSTRUCTIONS

TABLE MANAGER AND ERROR HANDLER

120

PARALLEL VLSI MACHINES REQUIRE
SPECIAL COMPILER FEATURES

- PRAGMA DECODER
  - READS SPECIAL DIRECTIVES AND TAILORS THE COMPILATION PROCESS

- TYPE ANALYSIS AND TYPE CONVERSION
  - CONTEXT ANALYSIS AND GENERIC OPERATOR, GENERIC FUNCTION, AND GENERIC PACKAGE INSTANTIATION

- HIGH LEVEL CODE SELECTION (HIERARCHICAL)
  - MATCHES CODE TO HARDWARE AND SOFTWARE MACROS

- HIGH LEVEL (HIERARCHICAL)
  - DATA FLOW ANALYSIS

- HIGH LEVEL (HIERARCHICAL)
  - RESOURCE ALLOCATION

- MULTITASKING ANALYZER
  - PROVIDES DATA ON RESOURCE UTILIZATION

121

SUMMARY

- ADA HAS AN APPROPRIATE SET OF FEATURES FOR PROGRAMMING PARALLEL SIGNAL PROCESSORS

  FACILITATES CONCURRENCY, HARDWARE PACKAGES, PERMITS STRUCTURED, RELIABLE PROGRAMS

- VLSI SIGNAL PROCESSING PUTS ADDITIONAL REQUIREMENTS ON THE ADA COMPILER

  NEW PRAGMAS, HIERARCHICAL COMPILATION, MACRO RECOGNITION/ SELECTION MODIFIED FOR STATEMENT

- SPECIAL PROGRAMMING GUIDELINES ARE APPROPRIATE

  AVOID PROCEDURES

  AVOID INDETERMINATE LOOPS

  AVOID GO TO'S

  HIDE PACKAGE BODIES

  MAXIMIZE USE OF GENERIC TYPES AND MODULES

  USE LOCAL TYPES

- ADOPTION OF ADA WILL EASE THE TRAINING PROBLEM

122

The PLRS/JTIDS Hybrid: Near Term Support of C^3 on the Battlefield

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Ground Systems Group

THE NEED

Significant challenges exist in Army command, control, and communications for the later 1980's and into the 1990's. The large number of emerging battlefield systems as included in the Army's Battlefield Automation Management Plan, provide a high degree of automation in support of the commanders in the various mission areas of fire support, air defense, maneuver, intelligence, and combat service support. This automation places increased emphasis on transfer of digital data and requires data timeliness on the order of a very few seconds rather than many seconds or minutes. The wide dispersion of sensors, command and control centers, and weapon systems place increased requirements on the ability of communications to support data transfer among units spread across the battlefield and to provide continuous performance against a hostile threat in mobile operations and in a variety of terrain conditions. Command and control architectures such as the Executive Control and Subordinate System allow more distributed battlefield C^2 and require significant communications across the various Army mission areas of each echelon of command, and demand that a cohesive means be provided to allow exchanges of information among battlefield elements whose equipments, formats, and communications devices do not currently fully support this type of operation.

In addition to needing more capable data distribution, command and control in the 1990's requires that the commander and his staff, as well as many of the C^2 computer data bases, have current and accurate knowledge of location of his forces and of other friendly forces both for force control as well as computer-aided weapons engagement functions. And it is desirable that the process of locating friendly forces be unobtrusive and undemanding of the time and resources of the units involved. For management of airspace and the ground regions, and for protection of friendly forces, it is important the mobile forces be able to be guided across the battlefield in accordance with updated constraints determined by the command and his staff.

Effective command and control in the late 1980's and in the 1990's demands that unit identification be provided reliably and accurately in near real time. In air defense, for example, it is critical that a fire unit immediately know whether an aircraft in its surveillance volume is hostile or friendly. A means for rapid and reliable identification of a friendly aircraft can significantly reduce current time consuming identification procedures, reduce probability of fratricide, and perhaps allow weapons free operations more often, resulting in increased air defense effectiveness. A friendly attack helicopter on a search and destroy mission can be made more effective by being provided near real time position and identification on friendly units in a complex battlefield.

In summary, to be effective, Army command and control into the 1990's requires capable battlefield support in the areas of data distribution, position location and navigation, and identification. And because the battlefield systems which must be supported are entering inventory in a few years, the Army has a pressing need, in the near term, for such a capability. And because of affordability, training, and battlefield proliferation considerations, it is desirable, if not necessary, that these three C^2 support functions be provided adequately by a single battlefield system.

The hostile threat to command and control is growing also. The expected use of active electronic counter measures including pop-up and stand-off jammers, self-screening jammers, and ground based jammers by potential sophisticated adversaries requires that the selected approach to meet the Army's C^2 support requirements be suitably jam resistant. Hostile employment of passive detection and processing techniques to attempt to detect, identify, locate, and target our C^2 elements also results in a requirement that the selected approach minimize probability of exploitation and provide capability to deceive hostile elements and avoid unique correlatable signature patterns.

From a performance point of view, the data distribution system selected to meet all three needs must be able to meet peakload data communications requirements while satisfying specified response time (end-to-end message communications delay) in the presence of the jamming threat and while conducting mobile operations in difficult terrain. All messages must be suitably cryptographically protected, and during peak loads, mutual interference must be sufficiently small to allow all performance requirements to be satisfied. Finally, and very significantly, the system must have sufficient reconfiguration capability so that continuity of operations can be provided in the event of outages to key elements in the battlefield.

The required system must be available in the near term, nominally the mid-1980's, with low risk. The weights and volumes of the equipments must be small enough to be supportable and to allow the host units and individual soldiers to perform their other functions without significant penalty. The costs of the elements must be low enough to make the system affordable when allocated to the selected users. Finally, since the system will be deployed subsequent to many of the supported battlefield systems, it must be able to be integrated with only negligible program impact on those supported systems.

DESCRIPTION OF THE PJH SYSTEM

The PLRS/JTIDS Hybrid (PJH) system was selected by the Army to meet its near term needs for support of C^3 in the battlefield. The Army has determined that the system will meet the Army's identified requirements for data distribution, position location/navigation, and identification and is the only alternative with equipments and software far enough along in development to be able to achieve an initial operational battlefield capability in the mid 1980's.

The PJH system integrates, with small hardware modifications and expanded data processing, the equipments and capabilities of two systems

completing development — the Army/Marine Corps Position Location Reporting System (PLRS) and the Joint Tactical Information Distribution System (JTIDS).

The PLRS system, which is completing engineering development and entering field testing later this year, provides the commander and the users with automatic and accurate position location, navigation, and reporting of this information to various battlefield elements. It also provides a capability for limited data communications. The PLRS system consists of two types of equipments — the User Unit and the Master Unit. In an Army Division, PLRS supports over three hundred users with small, lightweight, User Unit terminals designed for use in manpack and surface or airborne vehicles. The User Unit connects to a hand-held or vehicle mounted user readout device with an alphanumeric keyboard and display panel for message display and entry. A PLRS Master Unit, consisting of three computers, a PLRS RF terminal, a Display and Control Station, and other peripherals, configured in an S-280 shelter, performs centralized network management, user identification, distribution of free text messages, and the computation and display of all user unit locations in real time to an accuracy of fifteen meters. This position information can be made available to external command and control centers.

In operation, each PLRS User Unit periodically makes time-of-arrival measurements on other selected terminals and the Master Unit computes all position locations. The PLRS system entered full scale development in late 1976. Two Master Units and sixty-four User Units were built during this phase. PLRS will achieve an IOC in the 1983-1984 timeframe.

The other part of the hybrid system, JTIDS, is a tri-service, digital, communications system currently under development which provides automatic distribution of a high volume of data throughout a network. The JTIDS system also provides position location and identification of all users. When JTIDS terminals receive a message they use the time of arrival and included position information to calculate and update their own position estimates. The Class I JTIDS terminals, designed for use in large command and control centers, began development in 1974 and were successfully flight tested in the AWACS aircraft in early 1977. Subsequently, the size of the Class-One terminal was reduced by more than fifty percent, and the result was the Hughes Improved Terminal or HIT. HIT has now entered Low Rate Initial Production (LRIP). The Class 2 JTIDS terminal will provide a further reduction in size, a lower cost, and greater capability. This program will enter full scale development early next year and achieve an IOC in the mid 1980's.

Both PLRS and JTIDS utilize advanced technology including time division multiple access techniques, spread spectrum, frequency hopping, error detection and correction, and sophisticated signal processing to provide jam resistance and minimum mutual interference. Both are fully militarized systems containing integral cryptographic security. Both make extensive use of large scale integrated (LSI) circuits to minimize size and power consumption.

The PJH system builds on PLRS and JTIDS elements to support Army requirements in the Division area. Increasing interest exists in expanding its application to support elements in the Corps area as well. The PJH contains three primary equipment elements, shown in Figure 1: enhanced PLRS user units (EPUU), JTIDS terminals, and net control units (NCU). The low-cost manpack EPUUs are assigned to almost all Division units that participate in data communications, identification, and position location/navigation. Between 750 and 1000 EPUUs are assigned in the Division. The JTIDS terminals are assigned to those Division users whose data throughput requirements cannot be satisfied by the EPUU and/or who participate heavily in inter-service communications, such as air defense users who pass track data and who exchange friendly identification information with the Air Force. About 55-70 JTIDS terminal users exist in the Division. Finally, five NCUs are used in the Division, four being active and one being spare. One NCU is located with each Brigade and one in the Division rear area. A simplified illustration of PJH elements in the battlefield is shown in figure 2.

The EPUU is a modified PLRS user unit which performs user-to-user communications, measures and reports time-of-arrival information for position location/navigation, and serves as an automatic relay of opportunity, without interfering with its other functions, to extend communications range and keep communications paths operable even in the face of jamming and with changes in jammer dynamics and location. The modifications made to the PLRS user unit are: (1) firmware changes which enable direct user-to-user communications so that communications does not flow through a critical node in the battlefield, and (2) replacement of the PLRS user readout (URO) with an interface unit that connects to and accepts information from the various Army host system input/output devices, such as the Digital Message Device (DMD), that the Army has specified in its tables of organization and equipments (TOE). This allows the required spectrum of Army messages to be supported.

Two JTIDS terminals types are used for PJH: For initial development applications, versions of the Class I JTIDS terminal have the earliest availability. The fielded production PJH JTIDS terminal will be a suitably packaged version of the JTIDS Class 2 terminal.

The net control unit is a PLRS master unit modified to include an additional AN/UYK-20 type processor and a JTIDS terminal. It contains three AN/UYK-20 type computers and one AN/UYK-7. The display is a 19 inch CRT with a computer generated map background. It is housed on an S-280 shelter for transport on a 2-1/2 ton truck. It performs dynamic network management of all the radios (PLRS and JTIDS terminals) under its control and is the primary operator interface with the system.

BATTLEFIELD OPERATIONS

PJH system operations in the battlefield are characterized by automated network control in response to communications requirements entered and modified under control of the NCU operator and by robust continuity of operations capability.

126

The NCU operator is primarily a communications technical controller. He enters, via magnetic tape or the operator console, needline requirements which indicate communications paths to be provided (e.g., field artillery forward observer to the Direct Support Battalion Fire Direction Center with information copy to the Battery and Fire Support Officer) and desired message throughput rate and end-to-end message delivery times (response times) for each link. Needline data may also be entered remotely from the Signal Battalion S-3 System Controller (SYSCON), or, when authorized, by battlefield users. Needline requirements may be modified at any time. The display provides communications status monitoring information to the operator, indicating needlines which are satisfied or unsatisfied, connectivity problems (if any), capacity utilization, and hardware, software, and system alerts. The operator also can perform all PLRS command and control functions, such as entering corridors for vehicle guidance and specifying zones and boundaries for tactical control measures, etc. as a backup capability to the maneuver C^2 system.

The NCU computers perform the dynamic, real-time, automatic communications routing and timeslot assignments (for message transmission, relay, and reception) to the terminals to take maximum advantage of the multiple channel time division multiple access (TDMA) capability of PLRS and JTIDS. This crucial net management function is designed to continuously satisfy the communications requirements residing in the computer. For each specified needline, a pathfinding algorithm selects two independent paths from source to destination via relays of opportunity where necessary. The algorithm can utilize terminals as potential relays of opportunity and is able to locate a path even if only a single candidate exists in dense jamming. No dedicated or presited relays are required in normal operation. Dual paths are assigned to maintain maximum communications capability in a hostile and dynamic environment. The source, using packet-by-packet acknowledgement techniques, is able in real time to select the operable path when one path is broken to retain full service until the NCU replaces the broken path with another one. The PLRS and JTIDS terminals provide the NCU with updated data on the terminals they can hear from for use in path selection and in path monitoring. Timeslot assignments to each source, relay, and destination terminal are made by the resource allocation algorithm uses multiple frequency hopping channels for its community of terminals to increase available data communications capacity manyfold compared to basic PLRS. While initially the major area of technical risk, ongoing location and communications assignments. Contention operations are fully avoided, and adequate capacity exists for future growth. The NCU's resource allocationalgorithm uses multiple frequency hopping channels for its community of terminals to increase available data communications capacity manyfold compared to basic PLRS. While intially the major area of technical risk, ongoing net management definition and evaluation efforts have resulted in a design which is both implementable and capable.

The PJH system provides significant continuity of operations (CONOPS) performance. When a link breaks for any reason, the alternate path is utilized and the NCU rapidly and automatically replaces the broken link with another. When an NCU becomes inoperable, communications needlines remain satisfied initially since all terminal timeslot assignments are retained and no communications messages were allowed to be routed through the NCU. The terminals in

127

the community without an operable NCU rapidly and automatically join the adjacent NCU communities and are transferred to the NCUwhich has been assigned secondary responsibility for those terminals. At this point, full dynamic communications control of these terminals is reestablished. Upon restoral of the original NCU or replacement by the spare NCU, the reassigned terminals can be transferred back. This capability supports either unplanned sudden loss of an NCU or planned displacements.

INTEGRATION INTO THE BATTLEFIELD

The PJH will be supporting battlefield systems, some of which precede it into the battlefield. To minimize changes to those systems while allowing them to gain the enhanced support that PJH can provide, two architectural design decisions have been made. First, to support the full set of message types required by each system, the PJH terminal will be connected to and utilize the input/output devices, or computers, already part of the host system. The PLRS URO is discarded for these applications. Second, separate interface units are utilized by PJH to make the PJH terminals appear to the supported host systems as if it were connected to their current radio – such as the VRC-46 VHF FM radio or a multichannel set. Thus the PJH interface unit accepts signals from the host system in their current form (e.g., analog FSK for TACFIRE), and converts it into efficient bit oriented digital forms for transmission over PLRS or JTIDS. At the other end, the PJH interface unit converts the digital messages back into the form that the host system accepts. The functions performed by the interface unit during message transmission include signal conversion, de-interleaving and decoding (since error detection and correction, and crypto-graphic protection are provided integrally), data compaction and PLRS or JTIDS formatting under control of message type, and message partitioning into packets for each timeslot. For reception the inverse functions are performed including message concatenation or reconstruction, data restoration and refor-matting, encoding and interleaving, and signal reconversion. In Figure 1, an interface unit for TACFIRE conversion is shown attached to the enhanced user unit.

The PJH system provides integral cryptographic security. Both PLRS and JTIDS have proven cryptographic capability and the PJH approach builds directly on those elements.

Initial terminal allocations to the Division users have been identified. The Army currently is revising this allocation through preparation of its Basis of Issue Plan (BOIP) which is being based on the current Organizational and Oper-ational (O&O) Concept. Initially about 750 EPUUs are planned for the Division, including 306 for fire support, 148 for air defense, and 378 for maneuver, intel-ligence, and logistics. About 55 JTIDS terminals will be utilized, primarily at the command and control centrals and with heavy application to the high throughput air defense users.

ILLUSTRATIVE EXAMPLE

The utilization of PJH in the battlefield can be illustrated by simple examples for a field artillery and an air defense application. In Figure 3, the forward

128

observer (or FIST chief), composes a fire request message on his DMD which is automatically sent over his EPUU to the Fire Detection Center, as well as to the BCS and FSO for information purposes. The messages are transmitted directly or via relay if non-line-of-sight conditions exist, but the message never goes to or through the NCU. Previously, the NCU had made timeslot assignments to assure that these message needlines could be supported whenever in the future a message was going to be sent. The FDC computer receives messages from its EPUU originating from sources such as the TPQ-36, FSO, BCS, and FO and processes them in the usual TACFIRE manner. In response to the fire request discussed above, the FDC sends via its EPUU, tactical fire data to the BCS, which processes it and provides via its EPUU technical fire data to its guns and subsequently exchanges adjustment of fire information with the FIST. Direct communications via the EPUU between the FIST and BCS allow continuance of the engagement until an end-of-mission message from the FIST completes the process. The JTIDS terminals at the Direct Support FDC and the DIVARTY FDC support large computer data base transfers of fire support data that occur between these elements as well as transferring other shorter mission related messages. The Field Artillery School has shown that PJH can support its current doctrine as well as allowing alternative doctrines to be implemented at any time, a capability desired as the 1990's C^3 concepts evolve. The high performance, rapid speed-of-service capability of PJH support shoot-and-scoot operation, cannon launched guided projectiles (CLGP) operations, and greater mission effectiveness in a hostile electromagnetic environment.

The benefits of PJH to air defense C^3 are partially illustrated in Figure 4. PJH supports the requirements for C^3 netting of the sensors, weapons, and command posts in the Division forward and rear areas through its data distribution capability, its ability to provide accurate and timely cooperative ID data on friendly Air Force and Army aircraft to the gunners and command posts, and its ability to accurately locate participating units in three dimensions. Air defense units from the platoon and above, including the Forward Area Alerting Radars (FAARs), participate in the JTIDS network, sending high volume track, identification, and command information from the rear (Hawk, Patriot, Air Force via the Group Operations Center (TSQ-73)) to the forward elements. In the figure the JTIDS net passes Hawk and FAAR tracks, and friendly aircraft locations, to other JTIDS equipped air defense units. At the SHORAD platoon command posts, in accordance with the commanders C^3 criteria, some processed subset of this information is passed to the platoon's fire units via enhanced PLRS. Conversely surveillance data from the fire units are sent via the EPUU to the platoon CP's where it is processed, filtered and, according to C^3 procedures and criteria in effect at that time, passed rearward over JTIDS. In air defense, then, the PJH enhances the ability of C^3 to increase the effectiveness of the SHORAD units such as Stinger, Improved Chaparral or ROLAND, and DIVAD Gun. A SHORAD unit can use the EPUU connected to a Digital Communications Terminal (DCT) to quickly identify all friendly and enemy aircraft entering its sector and to provide surveillance coverage even though the fire unit's own surveillance sensor may be jammed or in emission control. The coordination between air defense elements and supported ground forces is also improved.

PERFORMANCE ASSESSMENT

To evaluate the ability of PJH to meet the Army's projected needs, an initial list of systems and intersystem interfaces to be supported were identified by the Army. This list included systems in each of the mission areas mentioned previously. The Army identified, after extensive review, all needlines to be supported for each system, including peak hour message rate, data content, and speed of service requirements.

Two primary performance measures best indicated in the battlefield context the ability of the PJH to meet its military objectives – percent of needlines satisfied and system capacity allocated and utilized. "Percent of needlines satisfied" indicates relatively how many of the desired communications paths can be supported in that sufficient battlefield connectivity exists to route messages between the source and destination(s) of that needline. "Capacity allocated" refers to how many timeslots must be assigned in the network, whether or not actually utilized for transmission of a message, to meet worst case data throughput and response time requirements. This must then be compared against existing system capacity to determine the degree to which the system has the resource to satisfy projected loads during peak hour periods. "Capacity utilized" refers to how many timeslots in which there are message transmissions. In many instances, such as in field artillery where many needlines are response time limited, time-slots are overassigned to provide the desired speed of service. The resulting lower utilization indicates less radiation density than is expected from "capacity allocated" and is important in assessing mutual interference.

A unique comprehensive simulation, validated by independent organizations, was utilized to assess these measures of PJH performance against projected jamming threats and in the European theater. Figure 5 illustrates the structure of the simulation, which includes locations of friendly and hostile equipments, parameters of the threats and PJH elements, details of the PJH net management and terminal operations, and propagation characteristics. Connectivity was determined to use as the basis for "% of needlines satisfied" as well as for determining numbers of relays needed for each needline so that capacity could be calculated.

Against the baseline jamming threat, well over 90% of the desired needlines could be satisfied without deployment of dedicated relays. In terms of PJH capacity, both the PLRS and JTIDS portions of the system were able to support all stated requirements with substantial reserve for future growth. Figure 6 shows "capacity allocated" for the baseline jamming level by mission area and for the total network.

DEVELOPMENT PLAN

After intensively evaluating the PJH system, the Army and the Office of the Secretary of Defense selected it for accelerated development. This allows an IOC to be achieved in the middle 1980's.

The selected accelerated development plan consists of a five phase development and test program (see Figure 7), utilizing a PJH testbed. Phase 1, system definition and concept evaluation, has been completed. Phase 2, currently underway, verifies the interoperability of PLRS and JTIDS by exchanging data between the two systems. Phase 3 establishes an interface capability with selected battlefield systems, completes the development of the EPUU, and provides an initial net management software capability for the NCU. Phase 4 provides a complete prototype system to be tested in-plant and sent to Fort Bliss, Texas for use with the SHORAD Command and Control testbed. Phase 5 completes the development of a division level system for operational testing at Ford Hood, Texas. The development/testing of the PLRS/JTIDS Hybrid will be completed in 1985, with a planned IOC of 1986.

CONCLUSIONS

The PJH system uniquely offers the ability to enhance C^3 capability in the near term and into the 1990's. It supports Army requirements for battlefield data distribution, position location, navigation, and reporting, and friendly identification. It can operate effectively in a hostile electromagnetic environment, in rough terrain, at peak loads with minimum levels of mutual interference, and with cryptographic protection. Its operations are consistent with tactical requirements and it can be integrated easily into the Army battlefield. As a result, the increased effectiveness inherent in the emerging battlefield C^3, sensor, and weapons systems will be realized.

PLRS
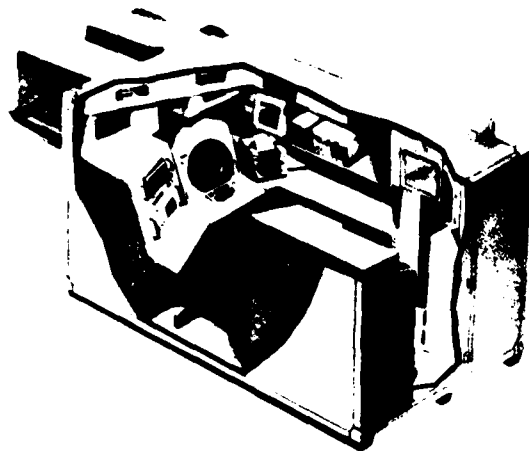
MASTER UNIT
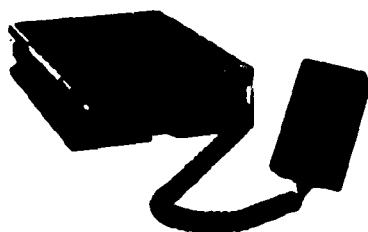
USER UNIT

JTIDS

CLASS 1
COMMAND AND CONTROL TERMINAL
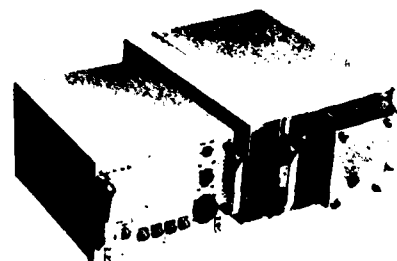
CLASS 2
(AIRBORNE CONFIGURATION)

PLRS JTIDS HYBRID

JTIDS ANTENNA
JTIDS TERMINAL

FREQUENCY
CONVERTER

FIRMWARE
MODIFICATION

INTERFACE
BOX

DMD

DCT
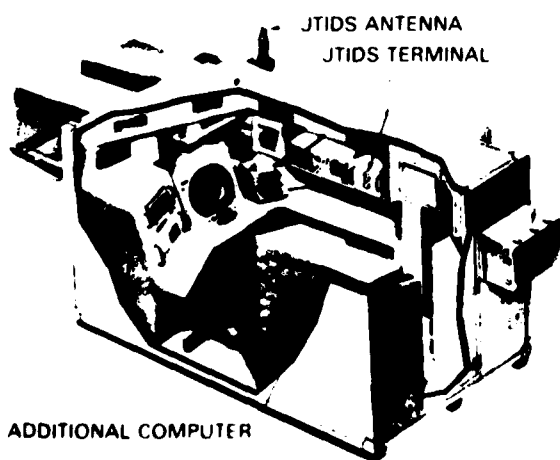
ADDITIONAL COMPUTER

NET CONTROL UNIT
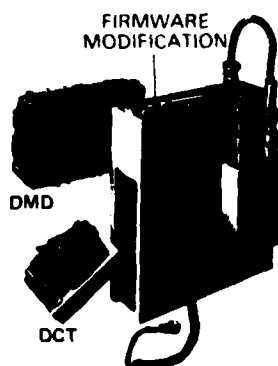
ENHANCED
PLRS USER UNIT

JTIDS - CLASS 2
(ARMY)

Figure 1. PJH Equipment Elements

132
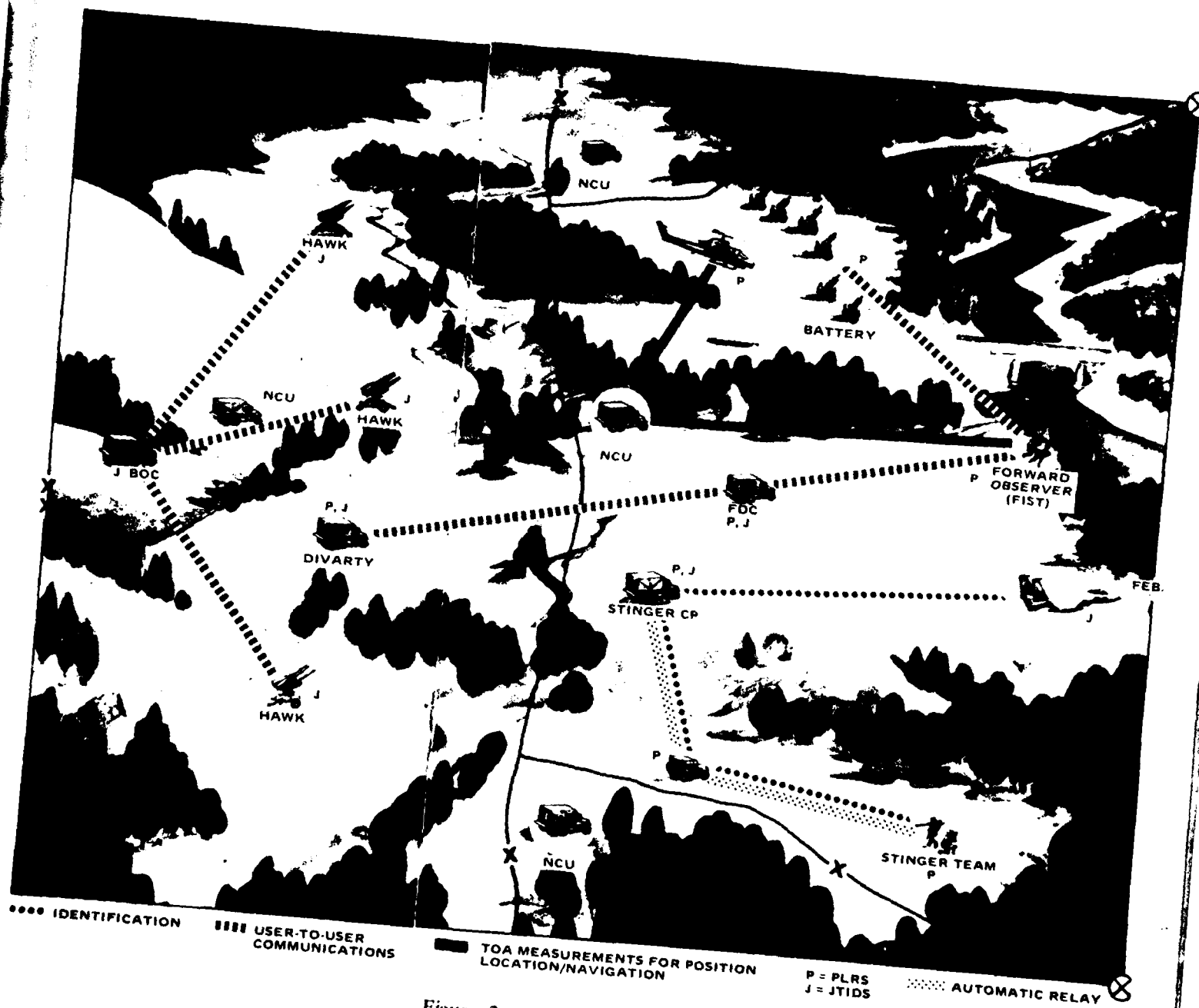
Figure 2. PJH in the Battlefield

Legend:

●●●● IDENTIFICATION

▮▮▮▮ USER-TO-USER COMMUNICATIONS

▬ TOA MEASUREMENTS FOR POSITION LOCATION/NAVIGATION

P = PLRS
J = JTIDS

∷∷∷ AUTOMATIC RELAY ⊗

Labels within figure: NCU, HAWK J, HAWK J, NCU, HAWK, J BOC, P, J, BATTERY, NCU, FORWARD OBSERVER (FIST), P, J, P, J, FDC P, J, DIVARTY, STINGER CP, P, J, FEB, HAWK J, P, NCU, STINGER TEAM P

133
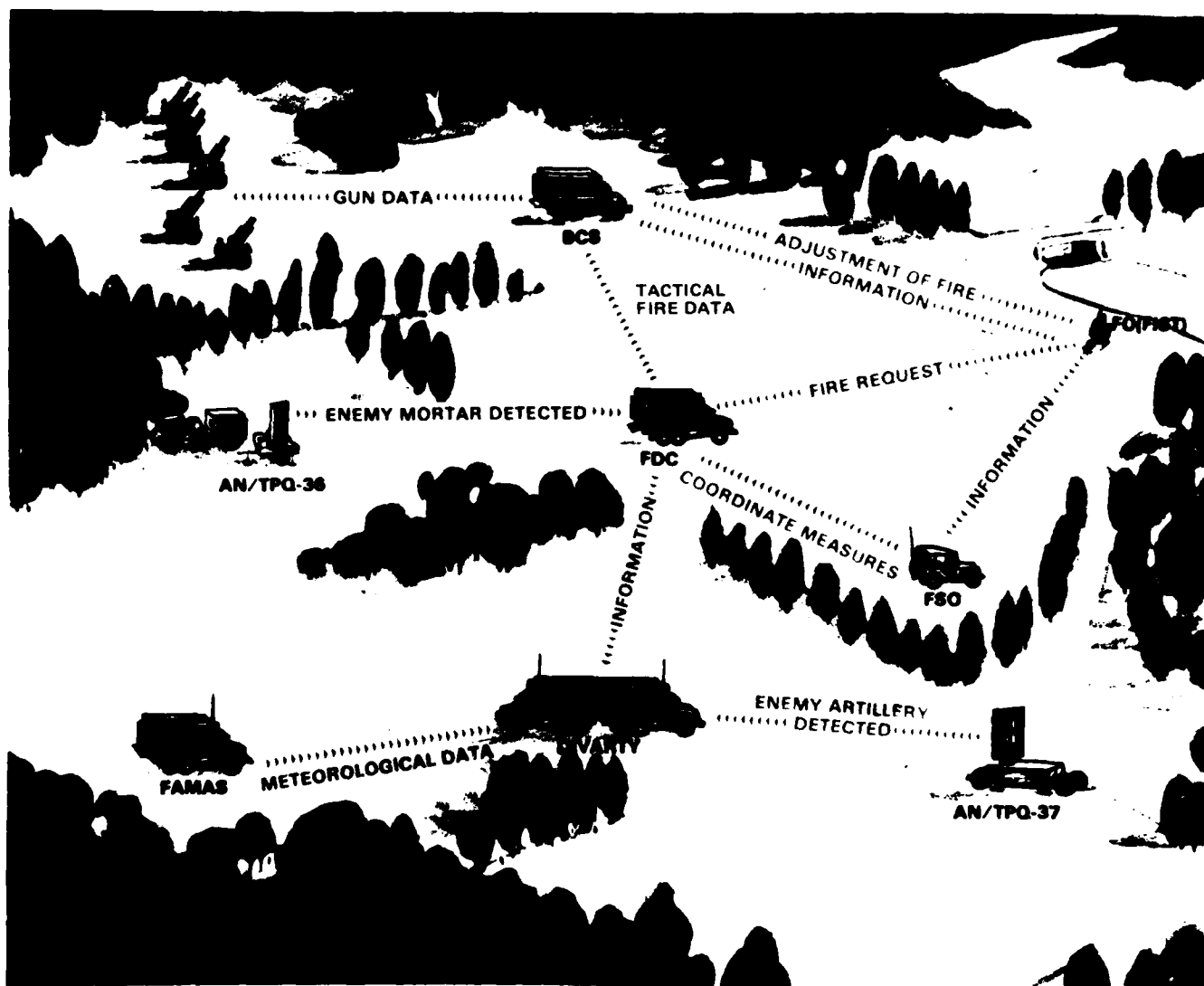
Figure 3. Support of Field Artillery C³

134
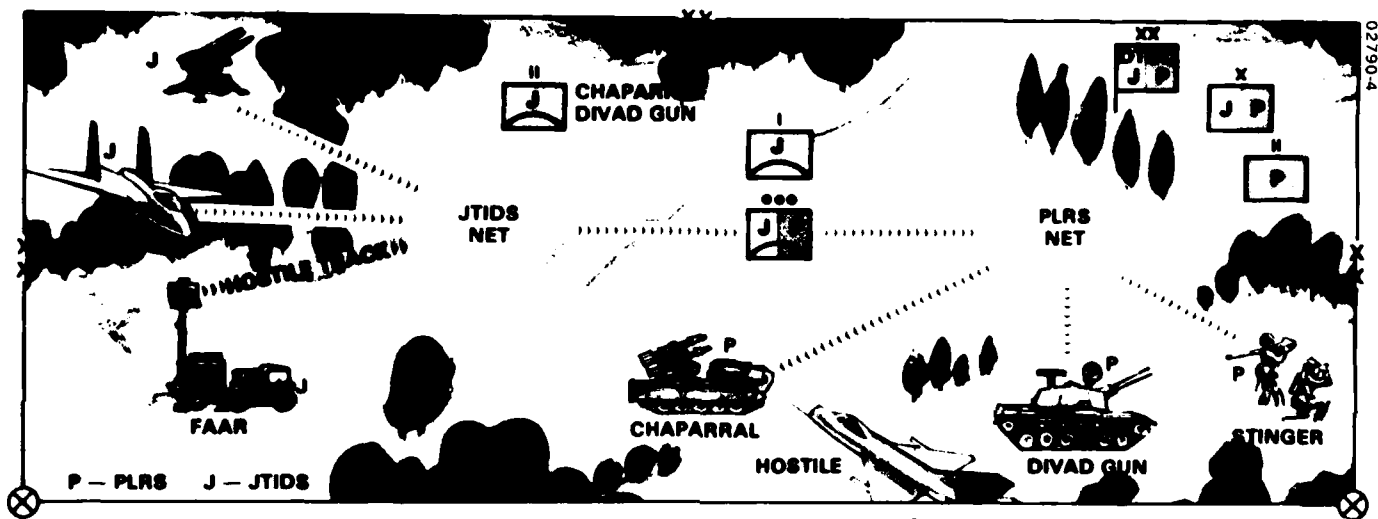
Figure 4. Support of Air Defense C^3
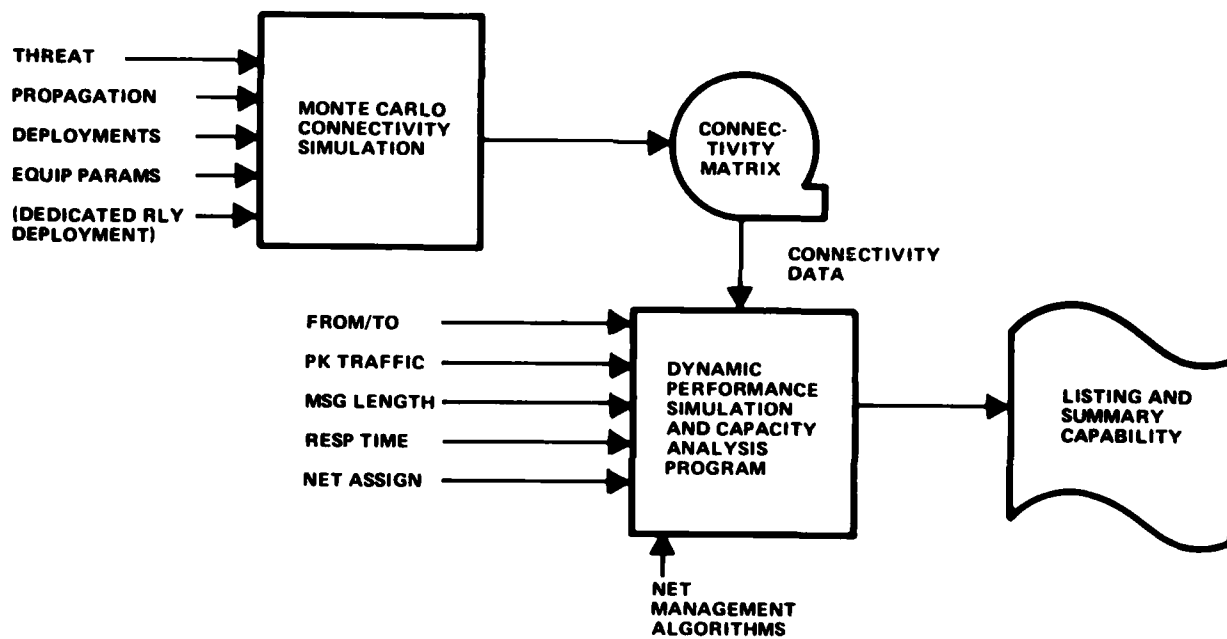
Figure 5. Simulation Structure
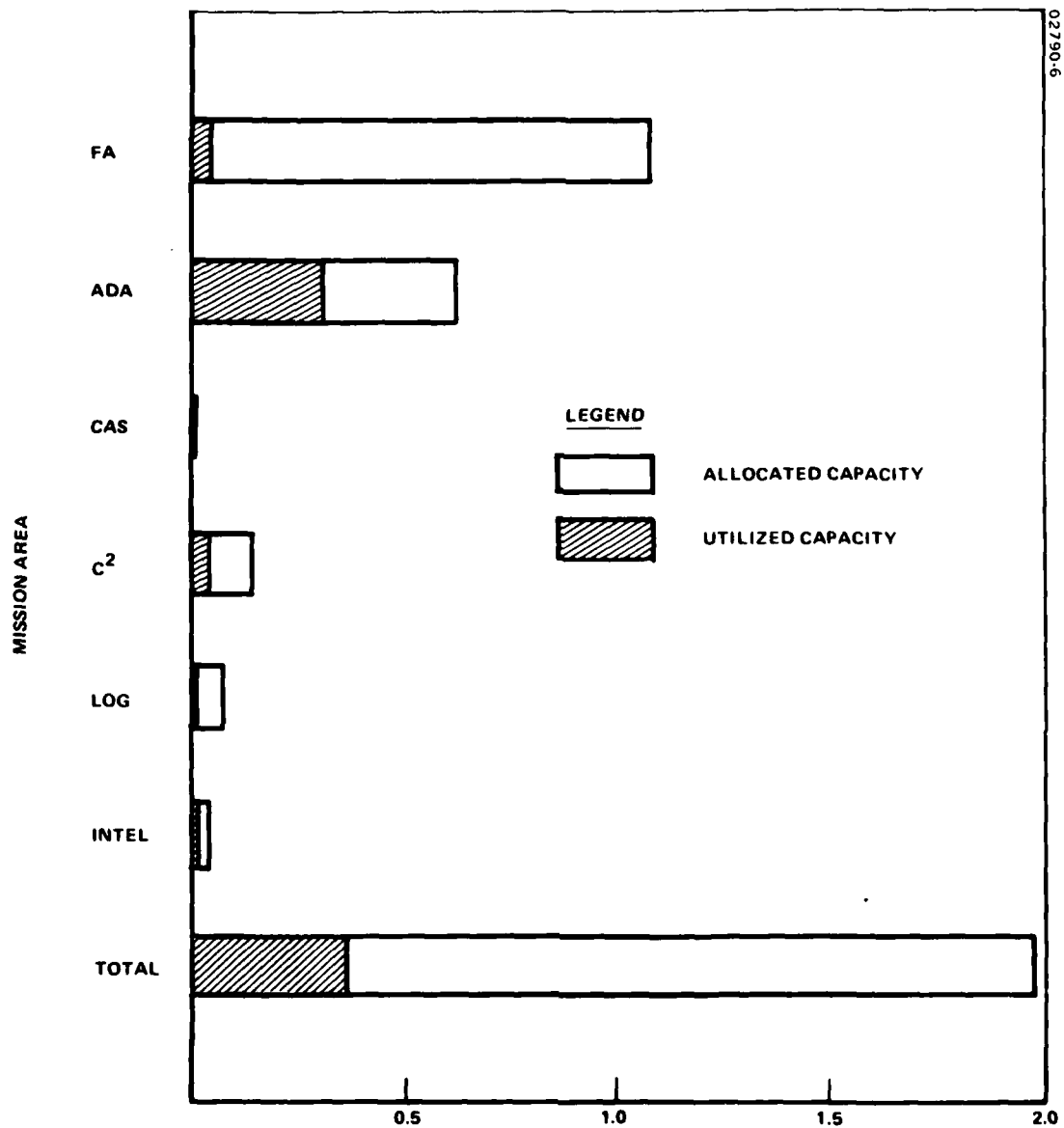
PLRS CAPACITY ALLOCATED FOR COMMUNICATIONS
(NUMBER OF FREQUENCY-HOPPING CHANNELS)

Figure 6. PJH Capacity Utilization

137
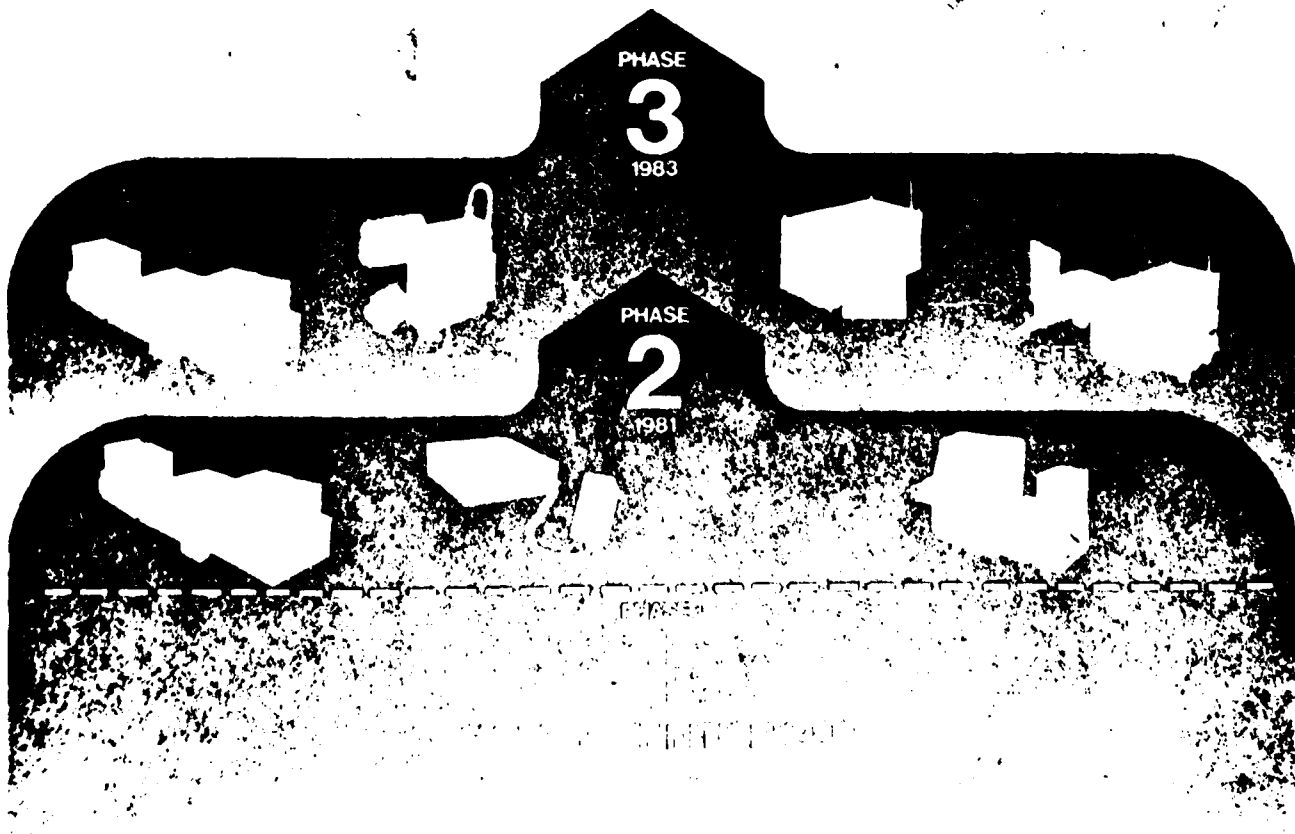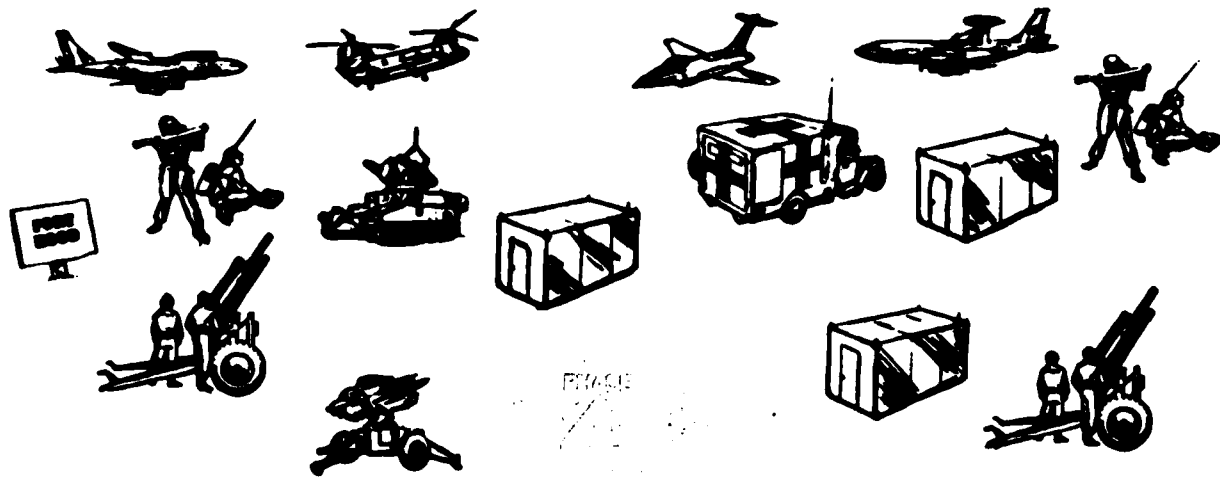
Figure 7. PJH Five Phase Evolution

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"Fire Support Control at the Fighting Level"

Barry L. Reichard
US Army Ballistic Research Laboratory

August 1980

A strong National Defense capability depends upon the ability of our US Army to respond to any type threat in any theater in the world. One of the most demanding missions is fighting against a mechanized threat where greatly increased mobility and lethality combined with the possibility of fighting outnumbered will result in an intensity of battle never experienced on previous battlefields. The Yom Kippur War was a sample of the kind of intensity of battle that can occur on the modern mechanized battlefield.

The objective of the US Army, however, remains unchanged - to win the land battle. Doing this on the modern battlefield, especially when outnumbered, will require the skillful orchestration of combined arms teams to concentrate combat power where and when it is needed most. On this dynamic battlefield, where command communication lines may be cut off intermittently, the battle must be fought and combat power must be applied by Captains and their companies, batteries, and troops under the general direction and control of brigade and battalion commanders (while higher levels of command should focus on concentrating the forces at the right time and place). Since a principal component of combat power is the firepower provided by the fire support system (Figure 1), the ability to plan, coordinate, and execute fire support at the fighting level must be a critical area of concern for US Army Research, Development, and Acquisition. [1]

As evidenced by Figure 1, the fire support system is quite complex in that it includes many parts with a wide variety of capabilities and operations, is widely distributed geographically over the battlefield, and has elements at all command levels and some from other services. Surprisingly, a little known fact (to nonartillerymen) is that the field artillery is responsible for integrating all fire support into combined arms operations as well as providing one form of fire support. In fact, it is because of the current field artillery organization and command structure that the lowest level at which integrated fire support for the fighting elements can be examined is the maneuver brigade. [2]

141

Normally an artillery battalion (bn) assigned the tactical mission of direct support (DS) is used to provide fire support coordination assets and artillery firepower to a maneuver brigade (bde). (Depending on assets available and the tactical situation another artillery battalion may be assigned the tactical mission of reinforcing to augment the fires of the DS bn.) A DS bn is still under the command of the next higher artillery force headquarters (HQ), division artillery (DIVARTY), but answers calls for fire in priority from the supported unit, DS bn forward observers (FOs) and target acquisition means (e.g., air observers), and last from higher force artillery HQ, i.e., a DS unit is the on-call artillery firepower for the supported maneuver brigade. If the brigade needs more fire support than that already available organically or through artillery fire support facilities, additional fire can be requested from DIVARTY, which for a mechanized infantry or armor division, includes two additional DS bns (for other maneuver bdes in the division), one general support (GS) bn, and a number (perhaps three) of battalions attached from corps in the form of an artillery brigade. The counterfire mission (attack of enemy indirect fire systems) is largely accomplished by DIVARTY and the attached artillery bde, whereas close (fire) support (attack of "close" enemy troops, weapons, or positions that threaten the force) is usually provided or arranged by DS artillery or organic mortars in support of maneuver brigades, the fighting elements.[2]

The fire support control facilities in a type mechanized infantry brigade are depicted in Figure 2. Fire support control is defined here to mean all operations necessary to cause the right fire support effect to reach the right destination at the right time, which therefore includes what is now called fire support planning and coordination and fire direction as well as control of devices to guide munitions to the target, e.g., laser designators. Fire support planning is the continuous process of analyzing, allocating, and scheduling fire support. Fire support coordination is the process of implementing that plan and managing fire support assets. Fire direction (FD) is the employment or execution of fire support firepower and can be either tactical or technical. Tactical fire direction is the selection of targets to be attacked, choice of fire support units to fire, selection of the best ammunition, and (with TACFIRE) consideration of fire support coordination measures. Technical fire direction is the conversion of calls for fire support (target location and type) into fire commands (aiming data) or as some think of it - solving the gunnery problem.[3]

In the brigade area (Figure 2), artillery fire direction is performed at the DS bn fire direction center (FDC) and at each of the battalion's battery FDCs, A, B, and C. Both 81mm and 107mm (4.2 inch) mortars are organic to maneuver units - an 81mm section of three weapons to each rifle company and a 107mm platoon of four weapons to both mechan-

142

ized infantry and tank battalions. Mortar FDCs are commanded by the maneuver unit commander, but the artillery fire support coordinators (FSCOORD) are responsible for integrating mortars into the fire support plan and for advising the maneuver commander on their use. As with artillery FDCs, the establishment and operation of fire support planning and coordination facilities are the responsibility of and the majority of personnel and equipment are provided by the field artillery. At each echelon from corps to company, a FSCOORD is responsible to the supported force commander for integrating all fire support means into the fire support plan and for advising the force commander on how to implement fire support. The FSCOORD is either the commander of the supporting artillery unit or a representative thereof.

In the illustrated brigade area, the bde FSCOORD is the DS artillery bn commander, usually a LTC. The bde fire support element (FSE) is operated by the bde fire support officer (FSO, a MAJ), the FSCOORD's full-time representative, and three enlisted men. It works in coordination with the bn FSEs (whose FSOs are supervised by the bde FSO), with the DS bn FDC, and with the main and tactical FSEs at the division command post (CP). At brigade and every level from battalion to corps, representatives of other fire support means are made available to the FSCOORD as shown in Figure 3. The bn FSO (a CPT) is the FSCOORD at the maneuver battalion level, and like the bde FSO, he is the principal advisor to the force commander (maneuver battalion commander in this case) on all fire support matters, recommends allocation of fire support, prepares fire plans, performs target analysis functions, and monitors requests for fire support. The bn FSE must coordinate its work with the fire support teams (FISTs), which are supervised by the bn FSO, other bn FSEs, the bde FSE, and the DS bn FDC.[2]

At the company (co) level, the FIST is the fire support organization. The FIST concept was recommended by the Close Support Study Group in 1975 to optimize observed fire support and subsequent to Department of Army approval in 1977, has been phased into the force structure.[4] Simply stated, the FIST concept combined the mortar and artillery FO organizations, called for new equipment like tracked armored personnel carriers (for FISTs working with mechanized units) and additional radios, and provided for training under a common military operational specialty (MOS). A "type" mechanized rifle company FIST includes three 2-man platoon FOs as well as a HQ manned by the FIST chief (a LT) and two enlisted men. Tank company FISTs do not have these platoon FOs or 81mm mortar sections. (If one of the maneuver bns in the mechanized infantry bde is a tank bn or if there is a mix of mech rifle and tank companies, the platoon FOs and 81mm mortar FDCs would be deleted in Fig-

ure 2.).

With the FIST concept, the additional role of fire support planning and coordination has been added to the traditional FO role - target acquisition and adjust-fire "sensor." The FIST Chief (CH) is the company commander's FSCOORD as well as the primary FO for the company. The FIST, under the supervision of the CH, is responsible for: locating targets and requesting and adjusting fire on them, planning and coordinating fire support, reporting battlefield intelligence, and at times, locally controlling other fire support measures such as close air support.[2]

FIRE SUPPORT CONTROL TEST BEDS
HELBAT-8 & ACE

Recent battle simulation analyses and field experiences have shown that fire support control (or as it is usually referenced, artillery command, control, and communications, C^3) is the key to improved fire support effectiveness and survivability. New fire support control doctrine and evolving user requirements are indicating the need for both fully centralized and fully decentralized control of fire support and all levels in between, so that control can be quickly tailored to tactical needs. With the automatic data processing (ADP) technology and concepts "dish" overflowing, the fire support control development problem can be compared to "boarding a speeding (technology) train" (in the context of a lethargic 8 to 10 year materiel development and acquisition cycle).

Test beds like the periodic HELBAT (Human Engineering Laboratory Battalion Artillery Test) field exercise can help in this problem area by providing a "vehicle" for the development and evaluation of alternative total operating system concepts and procedures. In light of the above introduction, it is no surprise that the main thrust of HELBAT 8 will be C^3 as indicated by the priority list (Figure 4), which was generated by the Field Artillery School at Ft. Sill. Further, with new doctrinal concepts like spread-battery emplacement, split 8-gun battery, and gun-and-run, there is a need to evaluate new tactical fire direction concepts at the battery level and automated position, pointing, and technical fire direction control on board the weapon. With the rapidly increasing need and difficulty of distributing data on the battlefield, as evidenced in HELBAT 7, there is a need to evaluate data distribution concepts and ways to reduce the data load such as the target integration center (TIC), which will convert the great magnitude of intelligence data to a smaller volume of confirmed target data.

With reference to line-of-sight (LOS) limitations experienced with forward observer (FO) vehicles in past HELBATs, concepts for increasing the observation capability from the fire support team (FIST) vehicle as well as air observer capabilities are to be evaluated. Since nuclear, biological, and chemical (NBC) protection is also a priority item, particular attention will be given to this area including if possible, the incorporation of NBC protection on some of the hardware concepts fabricated or modified for HELBAT 8.

New technology concepts to be evaluated in a fire support control system context should be compared to the new Tactical Fire Direction (TACFIRE) system as a baseline. The exercise should therefore be at a minimum in the context of a maneuver brigade area since this is currently the lowest level of TACFIRE tactical fire direction and the smallest integral fire support control area (See Figure 2). This will require a number of the following type "players" in the exercise: FOs, FIST HQS, battalion (bn) and brigade (bde) fire support elements (FSEs), battery (btry) and bn fire direction centers (FDCs), weapons, and perhaps company (co) and bn mortar FDCs. Considering this and the high-technology experimental equipment involved, HELBAT 8 will be quite an ambitious undertaking for a one-time 6-week exercise. To insure maximum usefulness and lasting significance, the exercise must be planned in as much detail as possible and be approached and followed with a set of integrated efforts as shown in Figure 5.

One of the first efforts will be the development of a fire support control simulator (a computer-based laboratory test bed), called the Artillery Control Experiment (ACE), to aid in the planning of HELBAT 8 and subsequently to serve as a continually available tool for the development and evaluation of fire support control technology, materiel, organizations, and operations. With ACE, fire support control problems can be analyzed, identified, and defined in a series of alternative system and scenario contexts which will be quite helpful in generating and evaluating experiment designs for HELBAT 8. Further, hardware, software, and "skinware" (human interface) technology and system concept opportunities can be explored without building complete dedicated hardware. Perhaps most importantly, ACE can be used to investigate the application of key research areas (such as artificial intelligence, gaming theory, and distributed decision processes) to the tough problem of fire support control automation. As well as providing a much needed tool for user development and evaluation of alternative organization and operation concepts, ACE may also be used as an automated command-post-exercise (CPX) trainer. General examples of possible ACE investigation areas include: computer assists at decision nodes, improvement of man-machine interfaces (e.g., natural and query languages), "intelligent" filtering of information presented to fire support

officers (FSOs), and short-hand graphics for responsive, simplified operations.

More specifically as described in Figure 6, ACE is an interactive, real-time, multi-player fire support control simulator. Initially it will be developed on an in-house computer system (a PDP 11/70 with UNIX operating software at the Ballistic Research Laboratory), but wherever possible, a common programming language (such as FORTRAN) will be used to facilitate the ease of exporting ACE or parts thereof to other organizations. ACE will be able to both accommodate and simulate tactical fire support control materiel, e.g., the TACFIRE Digital Message Device (DMD). Through simulation, tactical equipment availability problems can be avoided; "what if" changes can easily be incorporated and evaluated; and training spin-offs are possible. Through the accommodation of actual equipment, the time-consuming development of simulator programs can be avoided; hybrid mixes of (actual and simulated conceptual) equipment are possible; and automatic scenario-loaded testing could be performed. To tie all the system components (actual and simulated) together, i.e., to model the network and to characterize realistic communications queues and delays and simulate full-force scenario loads, a supervisory ACE program is being developed.

ACE has been established as a major effort and to effect integration, ACE personnel are actively involved in major HELBAT-8 planning meetings. A DMD has been acquired and a DMD simulator is nearly completed. The FIST DMD and the ACE supervisory programs are currently being written. Battery Computer System (BCS) software and hardware documentation has been acquired and the method of characterizing the BCS in ACE is now being considered. An example of the output of the DMD simulator is shown in Figure 7. Once the DMD program is called up, the commercial terminal CRT (cathode ray tube) display provides a response identical to that of an actual DMD. The figure shows the DMD status display as it has been just filled out interactively by the operator and shows the movable cursor at the keyboard bell volume position.

In the near future, ACE personnel will interface an actual DMD to the computer system and will meet with Field Artillery School personnel to decide on initial scenario and experimental design, with Army Communications Research & Development Command personnel to develop simplified communications characterization algorithms, and under the auspices of The Technical Cooperation Program Subgroup W Action Group 6 (TTCP-WAG-6), with United Kingdom researchers who have developed the Computer Aided Staff Trainer (CAST), a voice communications command-post simulator. Further ahead, a fire support control symposium may be co-sponsored with the Army Research Office to bring the best thinking of the

146

other services, industry, and universities to bear on fire support control problems.

In general, the planned order of ACE work will begin, as described above, with the most basic fire support control elements and continue with the building of higher-level brigade-area elements. The first system exercise will include the following elements: FO DMD, FIST DMD, Battery Computer System (BCS), and weapon. The bn FSE will be added as soon as this lower-level system is operating and some of the following issues are addressed: FIST concept (centralized vs decentralized; automatic decision making), use of graphics by the btry fire direction officer (FDO), and operations with on-board gunnery computers.

Concurrent with the running of ACE system exercises during the spring of '81, another pre-HELBAT-8 effort, the subset evaluations, will begin (at the Human Engineering Laboratory). In this effort candidate subsystems and interfaces will be evaluated and further developed for integration into HELBAT 8, which is now scheduled for the fall of '81. As of this writing the candidate systems described below are being considered and in many cases are already being tailored for inclusion in the HELBAT-8 exercise. These systems can be grouped into three basic functional areas: target acquisition, fire support control in the brigade area, and firing battery operations.

The HELBAT-8 target acquisition candidates are depicted in Figure 8. As in previous HELBATs, dismounted platoon FOs will operate from terrain vantage points with various laser range-finder (LRF) devices. These will probably include the tripod mounted Ground Laser Locator Designator (GLLD) and the Marine variant of the GLLD, the Modular Universal Laser Equipment (MULE), both with automatic data links to the DMD and with developmental or experimental north-finder modules for azimuth reference. Other prototype tripod mounted LRFs and the soon-to-be-fielded handheld LRF may also be included in the exercise for comparison. The developmental FIST vehicle with its vehicular mounted GLLD will also be included as an acquisition device with a key issue being line-of-sight (LOS) observation capability from positions accessible by the vehicle. To further address this issue, an experimental telescoping tower-mounted target acquisition/designating system (TADS) is being considered for inclusion. As requested in the HELBAT-8 priorities (Figure 4), airborne observers will also be included; some of these at least, will be equipped with stabilized TADS. Under the auspices of TTCP WAG-6, the participation of a tethered observation platform is being negotiated with a Canadian industry.

An experimental computer-based radar netting system will be demonstrated at Ft. Sill

147

later this fall. This system will be capable of automatically analyzing and integrating target intelligence data, from Firefinder (counterfire) radars and ground-based and airborne moving target indicators (MIT) radars, to form confirmed target data lists. Although this system does not (at this time at least) integrate all the brigade-area target acquisition systems, it is an existing hardware concept that could be used to investigate the full brigade-area target integration center (TIC) concept in HELBAT 8 and is therefore being pursued as a candidate for the exercise. Instead of employing active radar systems, the TIC may be "loaded" in the HELBAT exercise by magnetic tapes of time-ordered intelligence data recorded at the Ft. Sill demonstration this fall.

As shown in Figure 9, the netted radar TIC would be set up to actively input target data to the bde FSE and the bn FDC. The TIC will be interfaced to these elements through "super" DMDs that will be especially modified for HELLBAT 8 to permit alternative operation on wire line, standard push-to-talk radios, or automatic data distribution system (ADDS) radios. These super DMDs will also incorporate the HELLBAT-7 modifications, automatic polar-to-grid conversion and time-tag capability, and will be used by the other target acquisition candidates for data communications with one or more (multiple addressees) of the decision nodes in the brigade-area fire support control system (FIST HQ, bn FSE, bde FSE, btry or bn FDC), depending on the type mission that is being conducted at the time. Experimental commercial-hardware Packet (ADDS) radios, which will be mounted in environmentally controlled cases for ruggedization in the HELBAT field exercise, will be the primary communications means in the brigade-area system depicted in Figure 9. Although the Packet radios are not yet militarized and may not be the first ADDS radios to be fielded, in the HELBAT-8 time frame they are the only ADDS radios available to demonstrate dedicated high-technology data communication - the crucial key to reliable and responsive data-world fire support control and more specifically here, to the successful operation of the new-concept HELBAT-8 brigade-area system.

For the first time in any HELBAT exercise, the full fire support control spectrum will be played: fire support planning, fire support coordination, and tactical and technical fire direction. As shown in Figure 9, the players include both a bn and bde FSE, a btry and bn FDC, and technical fire direction on the guns. In the HELBAT exercise, both the bn and bde FSEs will be equipped with (industry-conceived) experimental smart, (flat-panel display) graphics terminals (called tactical graphics terminal, TGT) that will be programmed to automatically perform some fire support planning and coordination functions and will automatically monitor and display (with military symbols) standard TACFIRE messages. A standard

TACFIRE battalion computer center will be included as the bn FDC and it, like the other players, will be able to alternatively operate on the ADDS radios as well as on standard push-to-talk radios. At the btry FDC, graphics peripherals in the form of a printer and a plotter will be added to the BCS, and new software will be developed and used to permit the investigation of tactical fire direction at the battery level. An existing experimental digitized terrain analysis system may also be interfaced to the BCS. The btry FDC will be set-up and operate in a tracked vehicle with active NBC protection. This vehicle may be one of the prototype armored ammunition resupply vehicles (ARV) that was fabricated on a M109 howitzer chassis for HELBAT-7; the use of an ARV vehicle will afford the FDC a nonunique signature in the battery area.

The weapon systems, which will be included in the new concept brigade-area firing battery, are described in detail in Figure 10. Building on lessons learned with Howitzer Test Beds (HTBs) 1 and 2 in HELBAT 7, HTBs 3 and 4 are currently being designed and fabricated as follow-on efforts. Both new howitzers will incorporate ADDS radio automatic data links, on-board technical fire direction computers, gyro systems for local self-survey and pointing reference, and gunner display units (GDUs) and chief-of-section display units (CSUs). HTB 3 will be a fully integrated system using servos to permit even automatic laying (aiming) of the gun tube, while HTB 4 will incorporate hardware that has been developed for other applications. HTB 4 will utilize the gyro hardware that was developed for the Advanced Attack Helicopter and the FIST DMD hardware reprogrammed to perform modified point-mass gunnery as well as the standard TACFIRE data message terminal function. Both HTBs 3 and 4 will use automatic feedback from ballistics and fire control error sensors to investigate methods of improving predicted fire, and both will also be interfaced to the new prototype armored ARVs. A wire-line data link between the howitzer and the ARV is used for communications, and the ARV auxiliary power unit (APU) can supply electrical power to the howitzer as a redundancy option. Standard howitzers and ARVs will also be included in the new concept brigade-area for the collection of baseline comparison data.

A summary of the ACE-1 and the HELBAT-8 plans is depicted in Figure 11. Note that a complete standard TACFIRE brigade-area system (including the Variable Format Message Entry Device (VFMED) for the bn and bde FSEs) will be operated in HELBAT 8 to collect common baseline data against which the performance of the new concept brigade-area can be compared. Both the bde FSE and bn FDC will alternatively serve as standard and new-concept elements. Although the FIST chief and bn FSO may be separated from his respective HQ or element, this communications complication will not be played. Although not discussed

above, the following equipment, if available, will also be included in HELBAT 8: Marine Corps Digital Communication Terminals (DCTs, a digital data terminal with graphics), Mortar Fire Control Calculators (MFCC, a data-communications mortar gunnery computer), and the Field Artillery Meteorological Acquisition System (FAMAS, a system that can automatically update the met in TACFIRE). Also if time and resources permit, a scenario load will be developed to simulate a full brigade-area load on the btry and bn FDCs and bn and bde FSEs. As a final note, the following international equipment may be included in the exercise under the auspices of TTCP WAG-6: Australian mortar fire control calculators; Canadian Military Portable Artillery Computer (Mili PAC), for a battery FDC computer, and the companion Gun Alignment and Control System, an off-carriage automatic gun laying system; and a FH-70 towed howitzer through the United Kingdom.

References

1. Operations, Dept of Army Field Manual (FM) 100-5, 1 July 1976.

2. Fire Support in Combined Arms Operations, DA FM 6-20, 30 Sept 1977.

3. Field Artillery Cannon Gunnery, DA FM 6-40, ~ Nov 1978.

4. Close Support Study Group II (CSSG II) Final Report, US Army Field Artillery School, ACN 57393, 1 Feb 1980.

COMBAT POWER = FIREPOWER + MANEUVER

FIRE SUPPORT SYSTEM

TARGET ACQUISITION	WEAPON + AMMUNITION	PLANNING, COORDINATION & EXECUTION
Intelligence	Cannon	Fire Support Team Hdqs.
Forward Observers	Missiles	Fire Support Elements
Radars	Close Air Support	Fire Direction Centers
	Naval Gun Fire	Fire Support Coordinators
	Other Means	Staff Officers
		Forward Air Controllers
		Fire Support Representatives

Figure 1

FIRE SUPPORT CONTROL ELEMENTS
MECHANIZED INFANTRY BRIGADE AREA
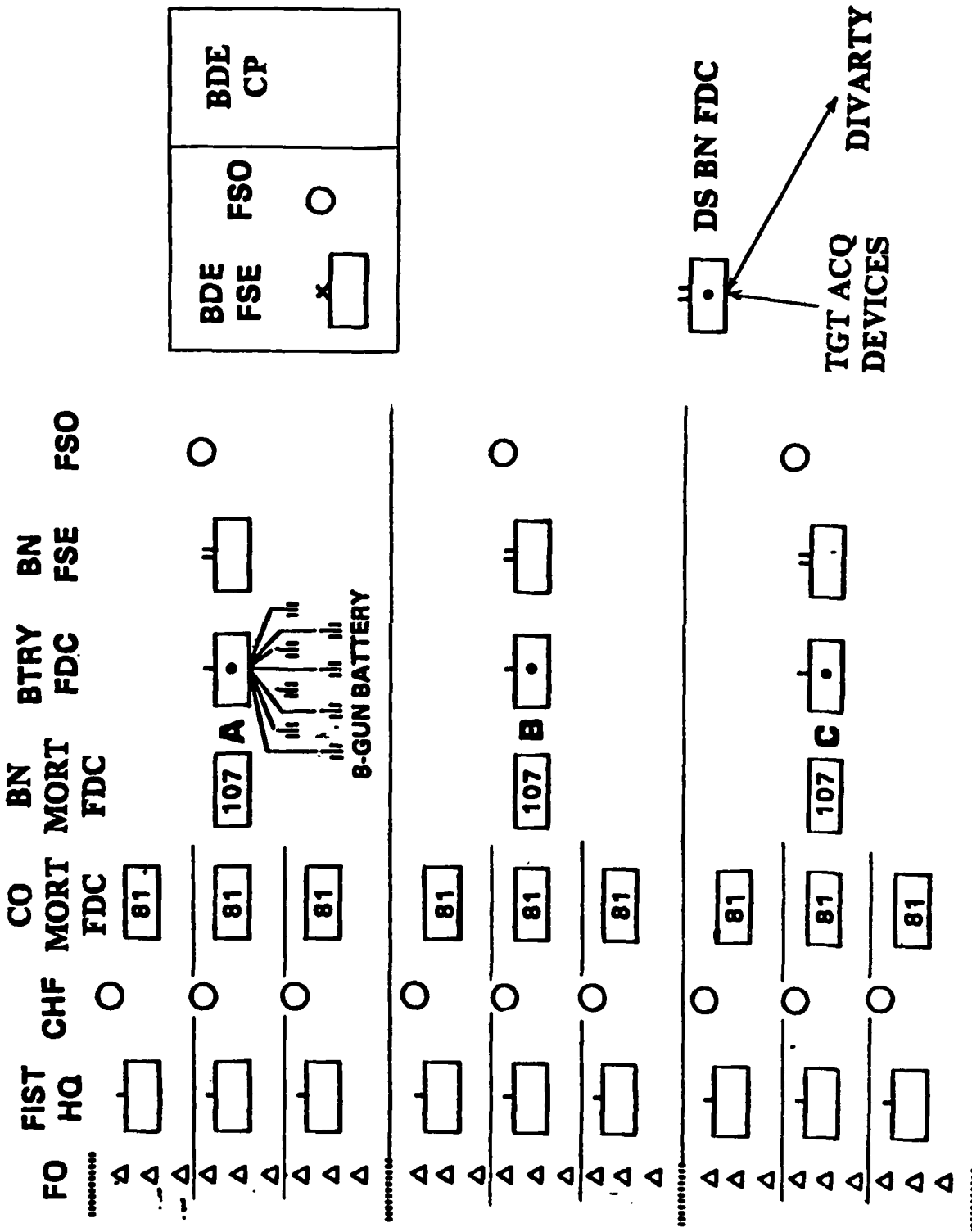
FIGURE 2

FIRE SUPPORT MEANS	ADVISOR	ECHELON
Field Artillery Fires	Fire Direction Center (FDC)	bn to corps
Battalion Mortars	Liaison Officer	bn only
Close Air Support	Tactical Air Control Parties/ Supported Force Staff Officers	bn to corps
Naval Gunfire (NGF)	NGF Representative	bn to div
Attack Helicopters*	Liaison Officer	bn to div
Air Defense Fires*	Liaison Officer	bn to corps
Indirect Tank Fires*	Artillery FDC	bn and bde

* In fire support augmentation role.

Figure 3. Fire Support Advisors available to the Fire Support Coordinator and his Fire Support Element Personnel.

153

FT. SILL
HELBAT 8 PRIORITIES

- C³
- AUTOMATED HOWITZER TEST BED TECHNOLOGY WITH INTEGRATED AMMUNITION RESUPPLY
- BRIGADE TARGET INTEGRATION CENTER CONCEPTS
- INCREASED LINE-OF-SIGHT CAPABILITY FOR FIST
- AIR OBSERVER
- NBC

154

Figure 4

FIRE SUPPORT CONTROL
TEST BEDS

INTEGRATED EFFORTS

- HELBAT-8 PLANNING

- ACE SIMULATOR DEVELOPMENT (at BRL)

- ARTILLERY CONTROL EXPERIMENT 1 (ACE 1)

- HELBAT-8 SUBSET EVALUATIONS (at HEL)

- HELBAT-8 (fall 81)

- HELBAT-8 ANALYSES

- ACE IMPROVEMENT & EXPANSION

FIGURE 5

155

ARTILLERY CONTROL EXPERIMENT (ACE)

INTERACTIVE
REAL-TIME
MULTI-PLAYER
FIRE SUPPORT CONTROL
SIMULATOR

- UTILIZES IN-HOUSE COMPUTER SYSTEM

- ACCOMODATES ACTUAL TACTICAL MATERIEL
  SAVES EMULATION, ALLOWS HYBRID MIX, AUTO EXPER

- SIMULATES TACTICAL MATERIEL
  EQUIP AVAIL, EASY "WHAT IF" EXPER, TRAINER

- SUPERVISORY PROGRAM
  MDL NETWORK, CHAR COMMO, SCENARIO LOADS

Figure 6

156

```
ORIG-A         DSPL DLY-0.8SEC
DEST-B         KBD BELL VOL-2
T/D-DATA       MSG BELL VOL-2
XMT BLK-SNG    WATT HRS-02.2
XMT RATE-0600  BATT LMT-12.0WH
PREAMBLE-1.7SEC
```

Figure 7. ACE-1 DMD Simulator
OUTPUT - DMD Status Display

157

HELBAT 8
CANDIDATE TARGET ACQUISTION SYSTEMS

PLT FO
GLLD NORTH FINDER
MULE
DMD

FIST/DMD NORTH FINDER

ELEVATED PLATFORM/DMD

AIRBORNE OBSERVER/DMD

TETHERED PLATFORM/DMD

NETTED RADAR/DMD

158
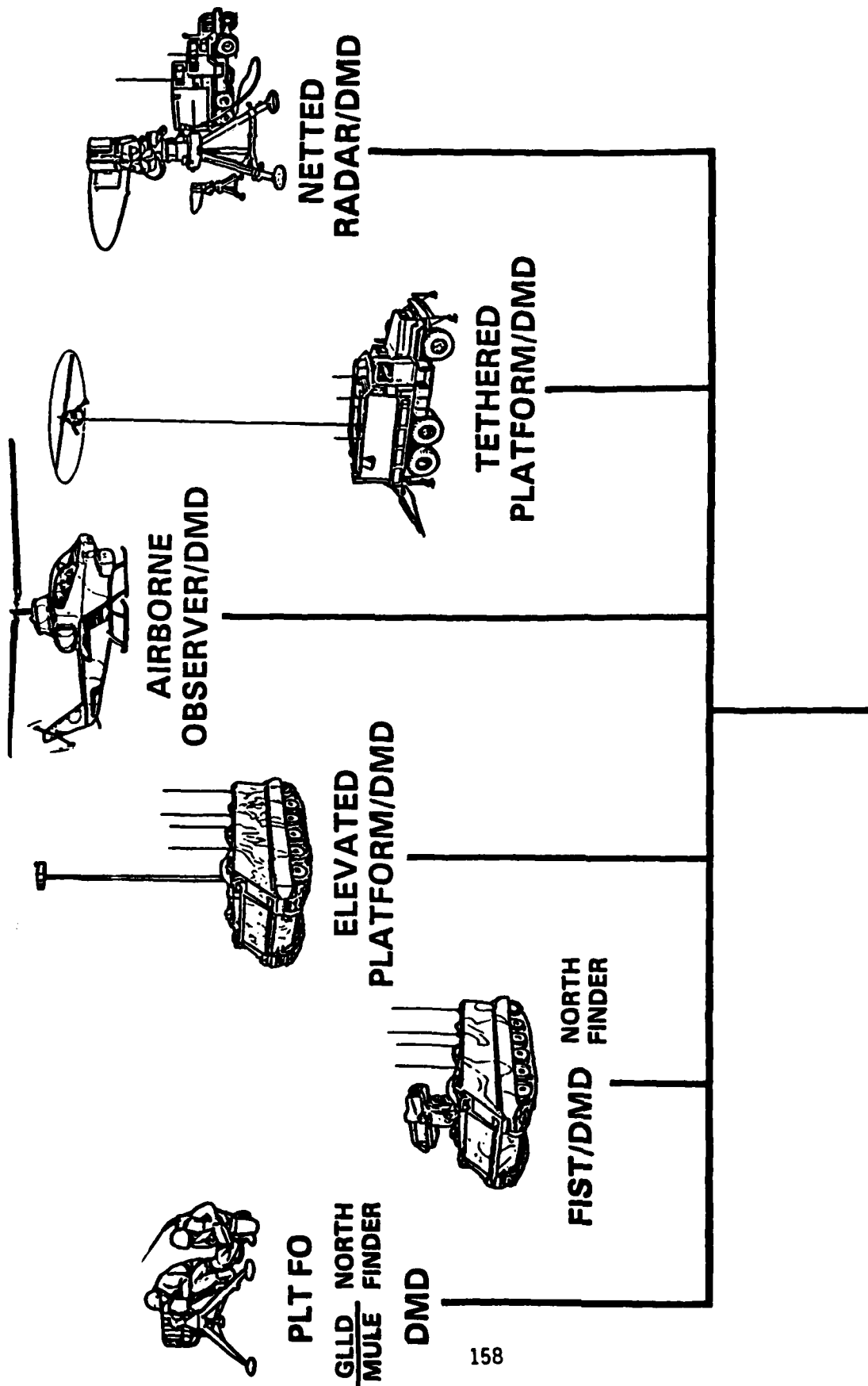
FIGURE 8

HELBAT 8
NEW CONCEPT
FIRE SUPPORT CONTROL ELEMENTS

TARGET INTEGRATION CENTER

ALL ON AUTOMATIC DATA DIST RADIOS

DS ARTY BN FDC (TACFIRE)

BDE CP

BDE FSE/FSO (SMART TERMINAL)

MNV BN CP

BN FSE/FSO (SMART TERMINAL)

FIRING BATTERY

AMMUNITION RESUPPLY

GDU CSU

POINT/NAV SYSTEM

TEC FIRE COMPUTER

HOWITZER

BATTERY FDC

ADVANCED BCS COMPUTER

TECH FIRE CONTROL

TAC FIRE CONTROL

DIGITIZED TERRAIN ANALYSIS

PRINTER

PLOTTER-DIGITIZER

DISPLAY/KEYBOARD

FIGURE 9

159

HELBAT 8
FIRING BATTERY SYSTEMS

STANDARD HOWITZER (M109A2)

WITH - WEAPON ERROR MEASUREMENT SYSTEM

STANDARD M 548 AMMUNITION CARRIER

HOWITZER TEST BED 4

- SELF-SURVEY/POSITIONING
- AUTOMATED FIRE CONTROL
- CREW DISLAYS/ERROR FEEDBACK
- TECHNICAL FIRE CONTROL COMPUTER
- ADDS RADIO
- POWDER TEMPERATURE
- VELOCIMETER

HOWITZER TESTBED 3

- SELF-SURVEY/POSITIONING
- AUTOMATIC GUN POINTING
- AUTOMATED FIRE CONTROL
- CREW DISPLAYS/ERROR FEEDBACK
- TECHNICAL FIRE CONTROL COMPUTER
- ADDS RADIO
- VELOCIMETER

AMMO VEHICLE-HOWITZER SYSTEM INTEGRATION

- INTER-VEHICLE INTERCOM
- APU POWER INTERFACE
- AMMO SERVICING CONVEYOR
- OVERHEAD PROTECTION

AMMUNITION RESUPPLY VEHICLE

- ON-BOARD CRANE
- IMPROVED PALLETING/STORAGE RACK SYSTEM

160

FIGURE 10

FIRE SUPPORT CONTROL ELEMENTS
MECHANIZED INFANTRY BRIGADE AREA

HELBAT 8
NEW CONCEPTS

BDE
FSE   FSO   TIC

SCENARIO ?
LOAD

FAMAS?

DS BN FDC
STD TAFIRE BN SET

HELBAT 8
STD RADIO
w/WIRE BACK UP

FO   FIST   CO   BN   BTRY   BN
     CHF   MORT   MORT   FDC   FSE   FSO
     HQ   FDC   FDC

TGT
VFMED

TGT

MFCC?

ADV BCS

HTB 3 4   STD
            M109A1

?

HTB 3 4

VFMED

STD BCS
wire
voice
STD M109A1s

SUPER
DMDs

DCT?

FIST DMD

STD
DMDs

ACE 1

107 A

107 B

107 C

81

161

FIGURE 11

MR. BARRY L. REICHARD

Mr. Reichard received his BS in Physics in 1965 from Lebanon Valley College in Pennsylvania. In 1967, he was awarded an MS from Franklin and Marshall College.

Mr. Reichard has been involved with planning, execution, and analysis of experimental programs in infrared, visual (optics), and laser physics as related to electromagnetic propagation and signatures of military targets and backgrounds. Later, he became involved in the development of computer methodology for the evaluation of field artillery syst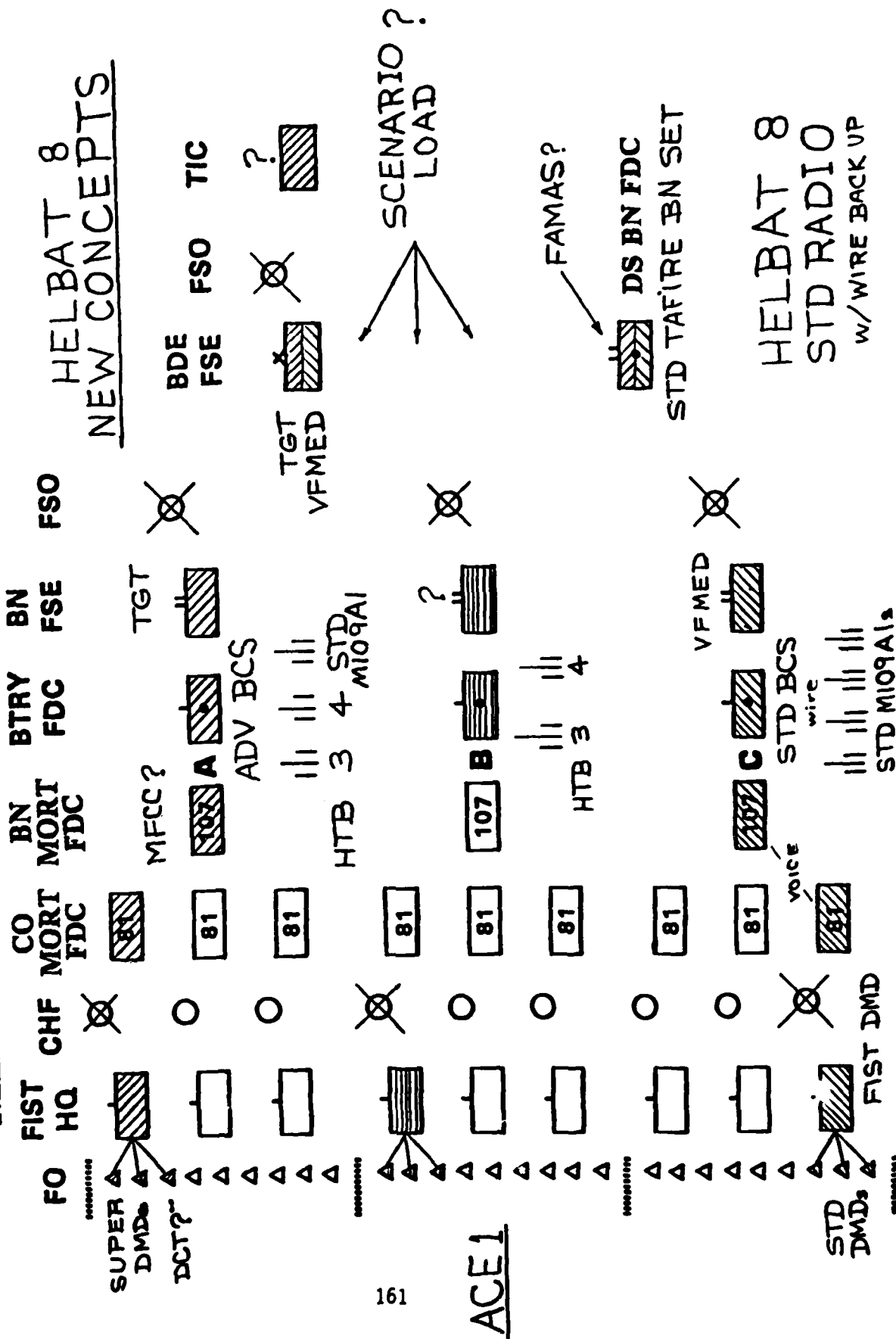em performance and effectiveness. Currently, Mr. Reichard is serving as a GS-13 weapon system specialist for planning, organizing, directing, and coordinating field artillery related research and development programs. He actively participates in field artillery systems activities such as HELBAT Working Group and Action Group 6 of Subgroup W, TTCP.

C^3 IN FUTURE TACTICAL SWITCHED NETWORKS

J. MULLINS AND S. HOMA
TRI-TAC OFFICE

INTRODUCTION

The Concept of Command, Control and Communications in tactical applications will become increasingly more important to battlefield commanders as future weapon systems become more complex and sophisticated. The demands put on the responsiveness and versatility of these systems will be translated into increased performance for tactical C^3 systems capable of operating at various echelons within the command structure which possess different information requirements with different methods of transmitting the information and using equipment operable over a wide range of environmental extremes. To achieve this objective the next generation of tactical switched communications equipment must include C^3 systems features such as responsiveness, survivability, security, flexibility and interoperability. The TRI-TAC system which will come to fruition during the 1980's will provide this capability.

TRI-TAC ARCHITECTURE FOR C^3

The TRI-TAC System Architecture is embodied in a series of annexes which coincide with eight functional subsystems: Nodal Switching, Static Subscriber Access, Mobile Subscriber Access, Communications Control Facilities, Trunk Transmission (Space), Trunk Transmission (Terrestrial), Ancillary and External Interface. In addition, numerous aspect papers are included for areas requiring special technical investigation and analysis. To describe the entire TRI-TAC Architecture is beyond the scope of this paper and therefore an attempt will be made to only develop those architectural considerations which pertain to C^3 operation in the tactical battlefield of the future, namely responsiveness, survivability, flexibility, security and interoperability.

Responsiveness. In order for a communications system to be responsive to C^3 requirements it must provide for information to be received by the appropriate ecision maker in a timely manner, i.e., prompt and useful. In developing the TRI-TAC architecture the factors which strongly influenced responsiveness are speed-of-service, quality-of-service, and grade-of-service. These characteristics are subsequently a function of call routing procedures, processing speeds, availability and maintainability of equipment, and overall system capacity.

The speed-of-service is accomplished by employing call routing procedures that are automated and software intensive to reduce the end-to-end call connect time as well as reduce operating personnel and increase system reliability. For message switch operation, features such as automatically relaying message traffic using header information, prompting during message composition and use of optical character readers will speed up message preparation for entry into the switch system. Near real-time data traffic is accommodated by the Unit Level Message Switches (AN/GYC-7 and AN/TYC-11) which can provide a speed-of-service of less than 1/2 second. Other features which enhance speed-of-service performance are direct access service, electronic switching technology and a system-wide channel transmission rate of 16/32 kb/s for voice, data and digital signaling.

Quality-of-service for voice traffic is generally reflected in the intelligibility of conversation which a battlefield commander may encounter. The measurement of this performance is accomplished using a Diagnostic Rhyme Test (DRT). To attain the necessary level of performance the analog-to-digital speech processing techniques selected for wide-band and narrow-band voice circuits are Continuously Variable Slope Delta (CVSD) and LPC-10 respectively.

Grade-of-Service is further improved by employing automatic alternate routing techniques in conjunction with a preemption capability. The larger circuit switches have the capability to select up to 5 alternate routes for each primary and to then preempt lower precedence circuits if necessary.

Survivability. The architectural considerations of survivability are composed of system survivability and equipment survivability. System survivability is provided by the application of distributed management and control elements which will assure overall network survivability despite loss of nodes and equipment. The alternate routing feature previously described will also aid in supporting survivability. Equipment survivability is a function of how well an item can operate in an ECM environment. The architecture addressed this area and postulated an initial ECCM strategy for early deployments with anticipation that future transmission equipment will employ increased techniques to combat enemy jamming.

Flexibility. The TRI-TAC architecture provides for the flexibility necessary to deploy varied communication resources in differing configurations. The required flexibility is provided by employing a four-level, hierarchical control system which includes a

Communication Systems Planning Element (CSPE), a Communications System Control Element (CSCE), a Communications Nodal Control Element (CNCE), and a Communications Equipment Support Element (CESE). The CSPE is management-oriented and will be capable of assisting in the preparation of initial deployments or reconfiguration of the overall network in response to known or anticipated future communications requirements. The CSCE provides the data processing capability needed to maintain a high performance of network operation, as well as adapt to changes in traffic demands, network configurations and equipment failures. The CNCE is the technical control facilities located within a nodal area to provide patching, monitoring, combining and the inter-connection necessary for the distributed switching and transmission facilities. The CESE includes the built-in test equipment necessary to monitor equipment performance and the telemetry facilities for sending this information to the CNCE.

To provide flexibility of equipment access the channel rate selected for the TRI-TAC Architecture is wideband, either 16 or 32 kbps, which will permit access by a wide variation of users. Any special conversion of input data to the wideband rate will be accomplished at the subscriber location, e.g., a data adapter, which will permit access by inventory data terminals. The analog to digital conversion process contained in the large circuit switches will allow inventory analog voice calls to be established between other analog subscribers or digital subscribers. This will enhance the transitioning from the current analog voice capability to the future all digital implementation.

Security. In the early stages of developing the TRI-TAC Architecture the security aspects were viewed as one of the key factors in the success of satisfying future demands for C^3. In order to satisfy these security requirements it became apparent the security capabilities would have to become totally integrated within the TRI-TAC system. The National Security Agency has been involved since the very beginning and has been a partner in the formulation of architectural development, specification preparation, and equipment development. This has resulted in a system being end-to-end secure with minimal effort while providing an overall reduction in equipment size, weight and power.

Interoperability. The interoperability aspect of the TRI-TAC architecture is addressed as part of the external interface as provided by various TRI-TAC subsystems. These capabilities will provide for interoperability with other US tactical systems, Defense Communications Systems (DCS), Allied tactical communications

systems, NATO Integrated Communication System (NICS) and commercial systems. There has been a continued on-going effort in many of these areas to insure that proper interoperation with different elements will be accomplished not only with current analog facilities, but with future digital equipments.

Interoperability can almost be categorized into each subsystem element, such as transmissions, switching (circuit and message), control, communications security, and data terminal equipment. For each category the interoperability requirements will actually include more than one external system. For example, the modular transmission hierarchy can accommodate the current inventory equipment group transmission rate, as well as the modularity of group rates necessary to interoperate with NATO, DCA, and commercial facilities. Other examples include compatible modes of data terminal equipments, digital voice processing techniques, analog and digital signaling, communications security, and orderwire.

The degree of interoperability provided by the TRI-TAC System will afford tactical units with an unsurpassed C^3 capability to operate in a joint tactical operation, unencumbered by limitations normally associated with these type of deployments.

TRI-TAC EQUIPMENT

In order to explain C^3 in the TRI-TAC system of the 90's, a brief description of the TRI-TAC equipment will be presented first.

The tactical automatic message switches are grouped in three general sizes. All process C^2 information in a digital secure mode. The largest is the AN/TYC-39 Automatic Message Switching Central providing 50 line or trunk terminations in any combination. It is housed in two S-280 shelters. The medium size message switch is the AN/TYC-11 Automatic Message Switch Central providing 12 lines for interfacing with other AN/TYC-11s, other message switches, circuit switches and data terminals. It is a rack-mountable configuration for inclusion in TRI-TAC's Modular Tactical Communication Center (MTCC). The small size data message switch is the AN/GYC-7 Automatic Message Switching Set providing 12 lines for interfacing with other AN/GYC-7s, the AN/TYC-11, and data terminals. It is configured as three "throw-on-the-ground" modules which are team-transportable.

The tactical automatic circiut switches, as indicated for the message switches, are grouped in three general sizes with each one capable of processing C^2 information in a digital secure mode. The largest is the AN/TTC-39 Automatic Telephone Central providing 600 lines in a dual-shelter configuration and 300 lines in a single shelter configuration. The medium size circuit switch is the

AN/TTC-42 Automatic Telephone Central providing 150 lines and can be depopulated to 75 lines. It is housed in an S-280 shelter. The small size circuit switch is the SB-3865 Automatic Telephone Switchboard providing 30 lines in two "throw-on-the-ground" modules. Two or three SB-3865s may be interconnected to provide an increased switching capability to 60 or 90 lines respectively.

The TRI-TAC family of digital terminals include secure voice, narrowband voice, facsimile, and single subscriber terminals. They are briefly described below:

The Digital Subscriber Voice Terminal (DSVT), KY-68, contains functions necessary to send and receive secure voice or data calls over a wide variety of switched digital networks. The DSVT data port accommodates the Tactical Digital Facsimile (TDF) and digital terminal equipment like the AN/UGC-74 single subscriber terminal. The Advanced Narrowband Digital Voice Terminal (ANDVT) is a ship, airborne, shelter or vehicle mounted subscriber terminal that provides for transmission of secure digital voice or data traffic over narrowband circuits. The Tactical Digital Facsimile (TDF) AN/UXC-4 provides rapid, high quality transmission and reception of typed or hand-written documents, maps, overlaps, sketches, charts, fingerprint records, and photographs. The Single Subscriber Terminals (SST) are configurable with 4 different modules: keyboard, printer, display, and auxiliary storage. The basic configuration is the Keyboard Printer (KP) AN/UGC-74. The other 2 modules can be connected to the KP when desired and the printer can be removed when the display is utilized.

The Modular Tactical Communications Center (MTCC) is the mobile tactical communications facility housed in an S-280 shelter. It provides means for message preparation, transmission and reception, storing, journaling, switching and plain language address to routing indicator conversion. The MTCC can be configured with SSTs, an optical character reader, high speed line printers, magnetic tape transports, TDFs, an AN/TYC-11 and a document copier.

To enhance interoperability on the battlefield the Secure Digital Net Radio Interface Unit (SDNRIU) KY-90 and the Mobile Subscriber Equipment (MSE) are being developed. The KY-90 is man-transportable, interconnects with any of the TRI-TAC circuit switches, and sends and receives C^2 traffic via single channel HF, VHF, UHF radios connected to a voice or data subscriber. It requires manual control for call set-up functions but performs automatic control for channel monitoring and receiver/transmitter switching functions after call establishment. The Mobile Subscriber Equipment (MSE) is a highly mobile tactical radio telephone

167

communications system. The MSE provides voice, teletypewriter, facsimile and data communications for and among mobile subscriber terminal users, switch system subscribers, information processing facilities and combat net radio users via the net radio interface. The MSE is comprised of the Mobile Subscriber Terminal (MST), the Mobile Subscriber Central (MSC) and the Access Unit (AU). The MST is a vehicular or airborne digital radio telephone set with integral COMSEC and performs automatic call processing. The MSC provides automatic integration of the MSE radio system into the static switched system, range extension for MST-to-MST communications and overall systems control and management. *The AU is collocated with unit level switches to provide interconnection between telephone subscribers and users of MSE.*

C^3 IN THE TRI-TAC SYSTEM OF THE 90'S

In the 90's the TRI-TAC Deployed Equipment will be approaching 90% digital. The network will support voice, facsimile, record, and data C^3. It will simultaneously handle intelligence information and support automatic weapon systems in the battlefield. C^2 traffic will be sent and received automatically across the interfaces to the DCS voice and message networks as well as to the NATO/Allies strategic and tactical systems. Automatic altrouting and automatic restoration will be employed. Two scenarios will be presented: one dedicated and one circuit switched C^3.

Dedicated C^3.

Figure 1 shows a scenario with battlefield-mission subscribers, record traffic subscribers, an AUTODIN interface, NATO interfaces, and an allied interface. Each subscriber will be given the capability to process and receive messages at the precedence levels appropriate to his needs. In addition to the traditional precedence levels (i.e., CRITIC, ECP, FLASH, IMMEDIATE, PRIORITY and ROUTINE), TRI-TAC has identified three additional precedences which are used for C^3. They are Network Control, Data I, and Data II. The Network Control precedence is the highest precedence enabling the network to be quickly reconfigured in the dynamic battlefield situation. Data I and Data II are the next two levels of precedences utilized by the battlefield mission systems. Real-time or near real-time mission-dependent data (Data I and II) will be processed by the Marine Integrated Fire and Air Support System (MIFASS), the Tactical Combat Operations System (TCO), the Position Location and Reporting System (PLRS), the AN/GYC-7, the AN/TYC-11 and the National Tactical Force, i.e., any NATO country deploying a tactical unit adjacent to the US.

In order not to lose the near real-time status of Data II
messages, age categories for Data I and Data II messages in
queue was developed such that a Data II message can be delivered
before a Data I message if the Data II message has been in queue
a significantly longer time, e.g., 3 times longer.

Together, the MIFASS, TCO, and PLRS will send 527 messages
to the AN/GYC-7 in one minute. In order not to cause a traffic
overload in the GYC-7, each message must be processed in
approximately one tenth of a second. The contractor for the
GYC-7, has proposed a message process time of 0.064 seconds for
both Data I and Data II messages. This time is achievable with a
distributed microprocessor architecture, direct memory access,
no reference or journal storage, an abbreviated message format,
and a 16 kbps input/output rate. The AN/GYC-7 and the AN/TYC-11
utilize TRI-TAC's Mode VII link protocol which is based on
FED-STD-1003 and approved by JINTACCS. Mode VII is very similar
to the X.25 draft standard being proposed in the international
arenas and it is planned that, in the 90's, the National Tactical
Forces, NICS/TARE, and other allies will be employing a link
protocol compatible with Mode VII. The abbreviated message
format utilized is called the Tactical Message Format (TMF) and it
is a condensed version of JANAP 128. (See Table I). The Routing
Indicators in the TMF are also condensed - 2 to 5 characters
instead of 4 to 7 characters. The first character is always an
"M" to differentiate it from the R, Y, or U community RIs. The
"M community" is converted to R community or U community RIs by
the TYC-11 when these messages are destined for the AN/TYC-39,
MTCC subscribers or National Tactical Force subscribers.

The MTCC/TYC-11 handles the origination and termination of
Y community intelligence traffic in addition to the M, R, and
U community traffic. The CRITIC precedence of the Y community
is directly below the Network Control precedence level which is
the highest level and is above the Data I and Data II precedences.
CRITIC traffic as well as other C^3I traffic (R and U communities)
is processed by the TYC-11 in a mean time of 3 seconds and by the
TYC-39 in a mean time of 2 seconds. One automatic altroute is
provided in the TYC-11 and two automatic altroutes is provided
in the TYC-39 for CRITIC traffic.

R, Y, U and NATO/Allies traffic can all be processed on the
same line where those interfaces exist as shown in Figure 1. Each
message, however, will contain only one community traffic and
stringent protections will be built in to insure the traffic is
not mixed. The R community in the TYC-11 and TYC-39 handles
Emergency Control Procedure (ECP) precedence traffic at the
same precedence level as CRITIC. ECP traffic is sent from the

highest command level and requires immediate action.

Circuit Switched C³

Figure 2 shows a scenario with battlefield-mission voice, facsimile and data subscribers. Some of these subscribers are connected remotely via radio to circuit switches, some are shown directly connected to circuit switches, and some are shown directly connected to message switches. Interfaces to the DCS and to NATO strategic and tactical systems are shown. Each subscriber will be given the capability to process and receive C^2 traffic at the precedence levels appropriate to his needs. Precedence levels available in the circuit switches are Flash Override (FO), Flash (F), Immediate (I), Priority (P), and Routine (R). All high precedence (FO, F and I) calls are non-blocking through any of the TRI-TAC circuit switches. Call processing times through these switches is less than 1 second for the AN/TTC-39 and less than one-half second for the AN/TTC-42 and SB-3865. The time to process calls between switches depends on many factors such as trunk signaling time, transfer of crypto keying variables, propagation delay time (especially for satellite links), noisy lines, possible crypto resync, and use of automatic alternate routes. In order to achieve this flexible system that is secure and survivable, many seconds may elapse before the call is transferred between switches.

Communicating with subscribers through half-duplex narrowband voice channels is seen as essential to the battlefield mission. The ANDVT with the KY-90 achieves this communications link to the circuit switches and thus to any point in the network. The ANDVT is kept small and rugged, yet it is secure. It essentially has a hot-line to the KY-90 which has an operator to key in calls to any DSVT for voice or data calls.

The MSE radio telephone system will have the capability for voice, data, or facsimile calls to be keyed directly from the MST thus eliminating the need for operator intervention and will provide for calls directly between MSTs.

SST subscribers off of the circuit switches will have the capability of sending digital data calls through the circuit switches to SST subscribers off of the AN/TYC-11 or AN/TYC-39 message switches. Likewise, the capability for sending C^2 data messages in the opposite direction is provided. The interface between the TYC-39 and the TTC-39 utilizes out-of-band trunk signaling messages that controls which interswitch trunk is to be used. The interface between the TYC-11 and the TTC-39, TTC-42, or SB-3865 utilizes

170

a simplified approach employing modified, data-only DSVTs, KYB-78s, with loop signaling. The KYB-78s are controlled automatically by the TYC-11.

The interface bewteen the TTC-39 and the National Tactical Force or the NATO Integrated Communication System's (NICS) Improved Voice Secure Network (IVSN) will be the multichannel digital gateway link which is now being formulated in the international arenas. It will be of the sole user type switched hot-line with automatic restoration. Using the hot-line (direct access service), subscribers will have the capability to directly signal other subscribers by going "off-hook". The connection is automatic and assigned the highest precedence. It is pointed out that hot-lines are also available in the TRI-TAC network of circuit switches.

The gateway to the DCS circuit switching network may be via the Secure Voice Improvement Program (SVIP) equipment. It provides for an improved and expanded secure voice service through the AUTOVON network. To the extent possible, specialized equipment and control functions peculiar to secure voice service, such as unique modems and cryptographic equipment, are planned to be positioned at DCS facilities to avoid burdening tactical units with additional equipment required to interface the DCS.

CONCLUSION

The TRI-TAC equipment that has been described is intended for use in Future C^3 applications and is the result of initial TRI-TAC architectural efforts. The TRI-TAC architecture should not be viewed as a final version of system/equipment implementation, but rather as a dynamic document, evolutionary in nature, which will accommodate future C^3 requirements as they are conceived and definitized. Further refinement of the TRI-TAC architecture will be undertaken in the future to take advantage of technological advances and new innovations.

Table I. Character Sets and Definitions for Tactical Message Format

| INFORMATION ELEMENT	BIT REPRESENTATION	CHARACTER REPRESENTATION
Start of Message	24 bits ASCII (8 bits/char)	3 alpha characters VVV
Precedence	4 bits	1 alpha character
Network Control	0001	C
DATA I	0010	A
DATA II	0011	B
ECP	0100	Y
FLASH	0101	Z
IMMEDIATE	0110	O
PRIORITY	0111	P
ROUTINE	1000	R
Classification	4 bits	1 alpha character
TOP SECRET	1000	T
SECRET	0100	S
CONFIDENTIAL	0010	C
UNCLASSIFIED	0001	U
Originator RI	16 to 40 bits ASCII	2 to 5 alpha characters
Message Type/ Characteristics	4 bits	1 alpha character
SYSCON message	1111	S
Perishable message	0000 through 0111	P
Nonperishable message	1000 through 1110	N
Station Serial Number (nonperishable message only) 000 to 999	12 bits BCD (4 bits/digital)	3 numeric characters 000 to 999
Addressee RIs (maximum 16)	16 to 40 bits/RI ASCII	2 to 5 alpha characters/RI
End-of-Routing Signal	8 bits ASCII	1 character Period (.)
	Message Text	
End of Message	24 bits ASCII	3 alpha characters QQQ

FIGURE 1 - DEDICATED C^3
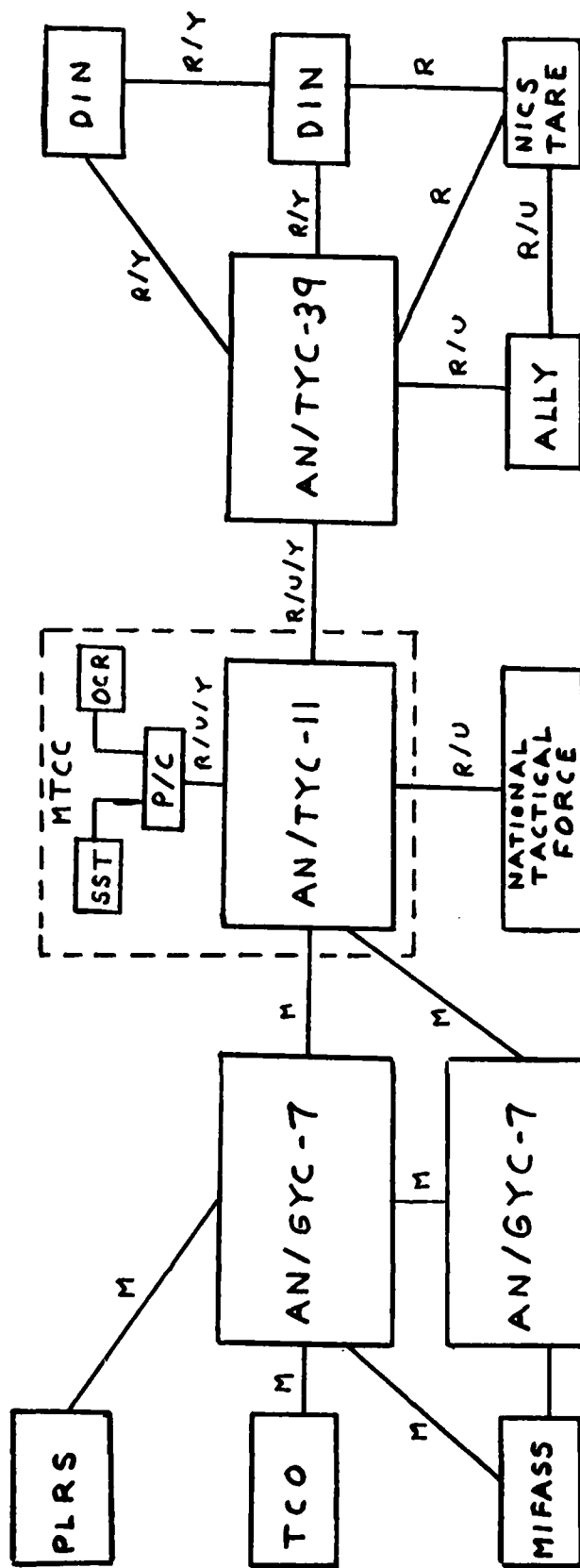
FIGURE 2 - CIRCUIT SWITCHED C³

BIOGRAPHICAL SKETCH

of

JOE W. MULLINS

J.W. Mullins was born in Des Moines, Iowa on July 30, 1938.
He received the B.S. degree in electrical engineering from
the University of Iowa, Iowa City, in 1962 and the M.S. and
M.B.A. degrees from Fairleigh Dickinson University, Rutherford,
New Jersey in 1971 and 1976, respectively.

From 1962 to 1966 he worked in the Combat Area Branch,
Transmission Division in the Army Electronics Research and
Development Laboratory.

From 1966 to 1973 Mr. Mullins worked on the development
of UHF and SHF tactical satellite ground terminal equipment and
advance spread spectrum satellite modems.

He joined TRI-TAC in 1973 and has been involved in the
preparation of the recommended TRI-TAC system architecture and
the preparation of specifications and plans for tactical
satellite communications and their application to tactical
digital switched networks.

BIOGRAPHICAL SKETCH

OF

MR. STANLEY HOMA, JR.

Mr. Homa joined Government service in 1958 as a civilian
electronics engineer for the Army's Signal Research and Develop-
ment Laboratories which is now CORADCOM at Fort Monmouth, NJ.
He worked 3 years in circuit switching design, 3 years in computer
design, 6 years in printing techniques and 5 years in OCR and
message systems. In 1975 Mr. Homa took a supervisory electronic
engineer position at USACEEIA-CONUS, Fort Ritchie, MD where he
led teams in engineering, quality assurance, and testing of
fixed-plant circuit switched systems and quality assurance and
testing of data communications systems such as WWMCCS and AUTODIN.
Since 1977, Mr. Homa has been employed by TRI-TAC, performing
engineering work on the message switches and recently being
promoted to a lead engineering position in the Systems Design and
Review Branch of TRI-TAC's Engineering Directorate. His accomplish-
ments include the following: Project Engineer of the AN/FST-6
Message Entry System which is still operating in the Pentagon;
Project Supervisor of the Forward Area Tactical Teletypewriter
guiding it to standard A; demonstration of tactical OCR and
MICROPAC Computer in 7th Army exercises; project engineer of a
miniature thermal printer which is still being produced; led
TRI-TAC coordination with JCS, DCA, DIA, NSA and the Services to
resolve interface problems between TRI-TAC Message Switches and
AUTODIN. Mr. Homa has a BS in EE from PITT, MS in EE from NYU,
and MS in Mgmt. Sci from FDU. He is a member of Eta Kappa Nu,
IEEE and AFCEA.

1.0

1.1

1.25   1.4   1.6

4.5
5.0
5.6
6.3
7.1

2.8   2.5

3.2   2.2

3.6

4.0   2.0

1.8

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
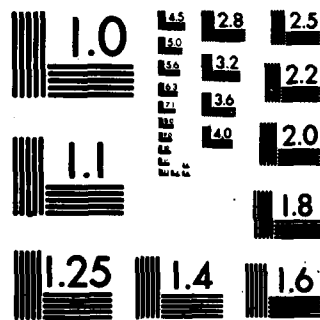
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Several papers by leading authorities address "The C³I Environment of the 90s". Furthermore, the collective efforts of the Army and Industry in countering the battlefield information explosion is addressed. The need for ultra reliable and survivable networks with high mobility and the ability to operate in an intense/adverse electronic warfare environment is also highlighted.

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177

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